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REGIONAL TECHNICAL REPORT
FOR SOUTHWESTERN COAL DEVELOPMENT
ENVIRONMENTAL STATEMENT
CLIMATE AND AIR QUALITY SECTIONS
FOR CHAPTERS 2, 4, AND 8

ERT Document P-3661-A

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DESCRIPTION OF CLIMATE AND METEOROLOGY

The ES region, which incorporates Uinta County, as well as portions of Sweetwater and Lincoln Counties, is contained within the broad geographic area known as the Great Wyoming-Big Horn Basin, a broad mountain basin interspersed with much irregular terrain. It is bounded to the west by the central Rocky Mountains and to the south and east by the southern Rocky Mountains. More specifically, the southwestern Wyoming coal development area (west of the Great Divide) includes the Bridger Basin and western foothills of the Wasatch and Uinta Mountains. The average mean sea level elevation is about 7,000 feet.

The ES region is closely bounded on all sides, except the south-central, by physical barriers of varying elevations. Table R2-1 presents a listing of mountain ranges bounding southern Wyoming. This table includes a range of peak elevation contours appropriate to each.

The northern boundary of the ES region consists of an east-west oriented ridge line comprising several relatively low mountain ranges (i.e., above the mean elevation contour). This ridge-line barrier could affect local air flow patterns but should not influence synoptic (large) scale weather systems.

The Laramie Range, which is an extension of the Front Range in Colorado, restricts the intrusion into the ES region of shallower domes of arctic air that affect Great Plains areas east of the mountains. However, deep layers of cold air can spill over the topographic barriers to the north-northeast (e.g., the Laramie Range) into the ES region, two to three times per year, although these arctic fronts typically recede within a few days.

In addition, during the winter the surface-based dome of high pressure, named the Great Basin High, which is typically centered in the region of northwestern Utah, northeastern Nevada, and southern Idaho, can build to sufficient heights above ground level, such that cold air can intrude into the ES region over the Wasatch Mountains. The intrusion of the cold air is characteristically associated with strong surface winds.

Furthermore, the high mountain ranges located west of the ES region (e.g., the Wasatch, Salt River) can induce significant vertical mixing downwind of them during strong upper-level winds that occur perpendicular to their orientation (Defant 1951). The forced lifting and associated cooling of air masses over these mountain ranges also contribute to substantial depletion of moisture emanating from the Pacific

TABLE R2-1

PHYSICAL BARRIERS IN SOUTHERN WYOMING

Boundary	Location	Mountain Range	High Elevation Range (feet)
North	Wyoming	Crooks	7,000- 8,000
		Ferris	9,500-10,000
		Green	8,000- 9,000
		Seminoe	7,500- 8,000
		Shirley	8,000- 9,000
		Freezeout	7,000- 8,000
Northwest	Wyoming	Laramie	8,000-10,000
Southeast	Wyoming/Colorado	Medicine Bow (Snowy Range)	10,000-12,000
		Park-Elkhead	9,000-11,000
Southwest	Utah	Uinta-Douglas	8,000-13,000
West	Utah	Wasatch-Bear River	8,000-10,000
Northwest	Wyoming	Salt River-Wyoming	9,000-11,000
		Wind River	10,000-13,000

*Note that basins in southern Wyoming range from about 6,500 to 7,000 feet.

(the ES region's primary source of moisture) by orographic precipitation (DAS 1971). Significant warming and drying of the air downwind of these mountains can occur along with the orographic precipitation (Defant 1951). Transient subsidence inversions with bases occurring approximately at mountain peak elevations on the downwind sides of these mountains are other features resulting from these conditions (DAR 1973).

General Climatology

The climate of the ES region is relatively cool and semi-arid in the basin areas; cool but subhumid conditions characterize the mountainous regions. The climate of the foothill and basin areas, the expected primary impact areas of coal development, is determined by the:

- latitudinal position (40°N)
- displacement from major sources of water vapor
- average mean sea level elevation
- surrounding physical barriers

The latitude of the ES region (40°N) positions it within the mid-latitude belt of westerly winds. This belt expands, intensifies, and migrates southward during the fall and winter. Synoptic scale storms* and associated precipitation generally occur most frequently during the winter and early spring. However, because the ES region is located within the central Rocky Mountain plateau, its climate is varied and substantially modified compared with other locales of similar latitude.

The mountain regions receive substantial amounts of precipitation as a result of the lifting of air masses over the mountains and increased storm activity during the winter and early spring (Becker and Alyea 1964a). However, because of this moisture depletion and subsequent subsidence of air downwind of the mountains, precipitation at the lower elevations is relatively light at these times of the year.

The period of March through June shows the highest frequency of precipitation, caused by free or forced convection. The combination of a higher moisture content of the air together with stronger solar heating contributes to this precipitation maximum. In the latter part of the spring, the mountains act as a high-level heat source, which promotes convection and subsequent precipitation from cumuliform clouds.

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*For a description of meteorological scales of influence, see the discussion on "Wind Fields" later in this section.

Because of the high elevation of the ES region, monthly mean temperatures remain relatively low. In addition, there is a large diurnal variation of temperature in the ES region associated with low water vapor content of the air and high frequency of clear skies. The diurnal variation is maximized in the summer because of lighter winds, strong solar radiation during the day, and rapid heat loss by terrestrial radiation at night.

Specific Climatological Parameters

The following subsections delineate the climate of the southwestern Wyoming coal development region according to several climatological variables. However, to present the climate of this area in detail, it is beneficial to address the broader geographic region depicted in Map R2-1. The State of Wyoming's Climatic Divisions are presented in this map, as well as the observation sites used in the regional study of the coal development area. The map also depicts the major topographic barriers outside the ES region that are so influential on the climate within the southwestern coal development area.

Sunshine

Although there are no sites within the ES region that routinely record the amount of available sunshine; Lander, Wyoming, located about 100 miles north of Rock Springs, experiences about 72% of the possible sunshine per year, ranging from 63% in the winter and spring to 78% in the summer and fall (Wyoming Natural Resources Board 1966). These values are somewhat above the state annual average of 65%, ranging from 55% in the winter and spring months to 75% in the late summer and fall. Since average relative humidities and precipitation amounts are lower in the basin areas of the ES region than elsewhere in the state, the percentage of possible sunshine in these areas would be expected to be slightly higher than the state's average values. On the western high plains and foothills to the Uinta and Wasatch Ranges (e.g., around Fort Bridger and Kemmerer), the sunshine would be expected to approximate the state's average conditions.

Wind Fields

A substantial data base of surface wind statistics recorded at sites within and appropriate to the ES region is not readily available. For the present study, five years of surface wind statistics for each of two stations were obtained to represent regional air flow patterns.

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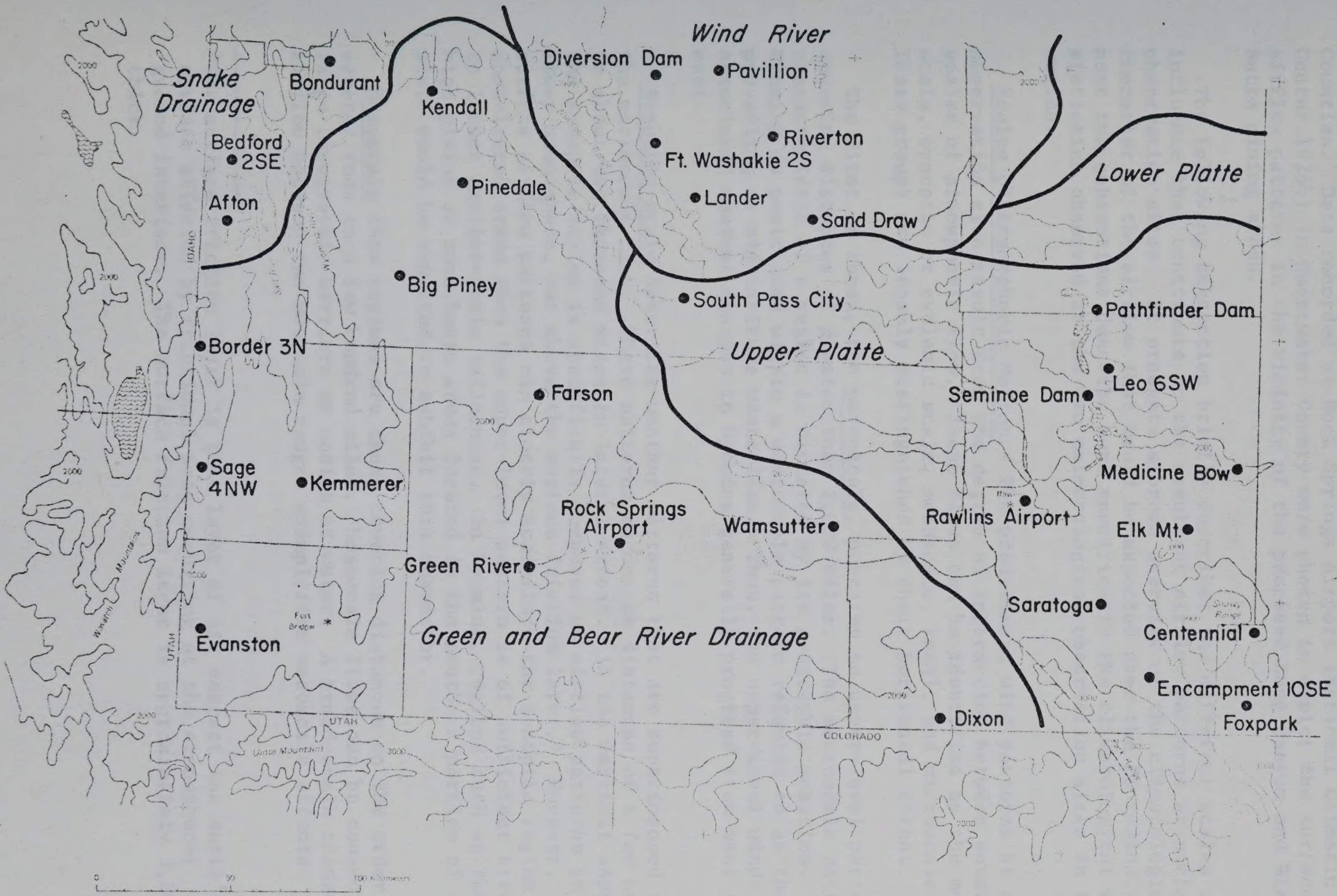

Wind River
Snake Drainage
Bondurant
Diversion Dam
Pavillion
Kendall
Bedford 2SE
Riverton
Ft. Washakie 2S
Lower Platte
Pinedale
Afton
Lander
Sand Draw
IDAHO
Big Piney
South Pass City
Pathfinder Dam
Border 3N
Upper Platte
Leo 6SW
Seminoe Dam
Farson
Sage 4NW
Kemmerer
Medicine Bow
Rock Springs Airport
Wamsutter
Rawlins Airport
Elk Mt.
Green River
Saratoga
Evanston
Fort Bridger
Green and Bear River Drainage
Centennial
UTAH
Encampment 10SE
Dixon
Foxpark
COLORADO
Uinta Mountains
Wasatch Mountains
Snowy Range
2000
3000
0
50
100 Kilometers

Map R2-1

Wyoming Climatic Divisions (dark lines) and Monitoring Stations (dots)
Used in Regional Coal Development Study
(Contour heights are in 500 meter intervals.)

Data collected at Fort Bridger Airport (National Climatic Center 1976a), located in Uinta County, were selected to represent meteorological conditions in the proposed coal-mining areas within Uinta and Lincoln Counties. Data recorded at Rock Springs Airport (National Climatic Center 1976b) in Sweetwater County were chosen to depict the surface airflow patterns in the vicinity of the proposed Long Canyon and Black Butte mining areas.

The following subsection briefly describes the different scales of influence that contribute to the resultant airflow patterns at surface observation sites. It presents a broad overview of the climatological character of the airflow that would be expected over the ES region. The next two subsections describe more specifically the climatological wind statistics observed at the two meteorological observation sites in the ES region.

Scales of Atmospheric Motion. The predominant wind patterns at an observation site result from the degree of interaction between several scales of atmospheric flow. These flows can be identified as the macroscale, synoptic or cyclonic scale, mesoscale, local, and microscale. These groups are loosely distinguished by their horizontal extent.

The first of these, the macroscale, pertains to upper-level patterns covering distances of greater than 2,000 miles. The macroscale pattern characteristic of a region is dictated by its geographic position. Wyoming is positioned within a macroscale pattern referred to as the prevailing or mid-latitude westerlies. Thus, the upper-level winds and associated weather changes in Wyoming generally progress from west to east.

Synoptic scale describes weather patterns that are superimposed on the macroscale flow. These patterns encompass distances of a few hundred to about two thousand miles in lateral extent. In the vertical aspect, the synoptic regime is specifically composed of airflow patterns in the lower atmosphere, but above the surface friction layer.* However, surface airflow patterns can closely assimilate the synoptic regime in unsheltered areas when the upper-level pattern is of sufficient strength to lessen smaller-scale influences. In Wyoming, regions such as the high plains or open basin areas located in the southern portion of the state would be expected to exhibit this character.

Mesoscale flow regimes are those covering distances on the order of several tens to a few hundred miles. Mesoscale flows can be caused by large topographic barriers or bodies of water. A broad-scale channeled airflow between two mountain ranges exemplifies mesoscale effects.

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*The surface friction layer is that layer of air nearest the earth's surface affected by frictional drag occurring at the atmosphere/ground interface. The surface friction layer is approximately 3,000 feet thick.

Local airflow regimes can result from influences similar to those on mesoscale patterns but are more confined in their lateral extent. A mountain valley circulation is an example of a local airflow pattern.

The *microscale* regime reflects fluctuations in airflow over horizontal distances ranging from a few to several hundred feet in length. Microscale disturbances can result from small variations in shading, terrain contours, vegetation, and/or soil characteristics.

Since a significant portion of the ES region consists of broad basins (for example, the Bridger and Great Divide Basins) or open plains, which are displaced from sheltering effects caused by narrow and/or steep mountain valleys, the surface airflow patterns would be expected frequently to reflect the synoptic region. However, site-specific differences would be expected to result from the mesoscale influence of site orientation from the large mountain ranges (Uinta, Wind River, etc.) surrounding the ES region. Climatological statistics, in the form of wind roses (the joint frequency of wind direction and speed), confirm this expectation for southwestern Wyoming.

Frequency of Wind Direction and Speed in Uinta and Lincoln Counties. Figure R2-1 presents the annual wind rose for Fort Bridger, Wyoming. It is based on five years (1950 to 1954) of hourly wind observations. Fort Bridger is located in Uinta County about 35 miles east of the Utah-Wyoming state boundary at an elevation of 7,000 feet. Fort Bridger is situated between the high mountain barriers comprising the Salt River and Wyoming Ranges (having a north-south orientation), positioned about 80 miles to the north and the east-west oriented Uinta Mountains 35 miles to the south. The Wasatch Range, having peak elevations of between 8,000 to 9,000 feet mean sea level, is located 80 miles to the west of Fort Bridger.

As indicated in Figure R2-1, the prevailing wind direction is west-southwest, which occurs 25% of the time. The annual average wind speed associated with this direction is a substantial 20 mph. The second most prominent (by frequency of occurrence) wind direction, west, is shown to occur more than 23% of the time, and has an associated annual average speed exceeding 18 mph. In fact, winds emanating from the west-southwest through the west-northwest (236 to 304°) occur about 64% of the time, with an average speed exceeding 18 mph annually. The annual average wind speed for all wind directions is 15 mph, which is high relative to a majority of locations throughout the country, but generally characteristic of high and/or open plains areas.

The direction of the surface airflow at Fort Bridger indicates the predominance of the synoptic wind regime that is characteristic of this region. Furthermore, the predominant west-southwest to west-northwest winds and their associated high average wind speeds could also depict the mesoscale effect of the confluence (convergence) of air between the major topographic barriers positioned to the north and south of the site.

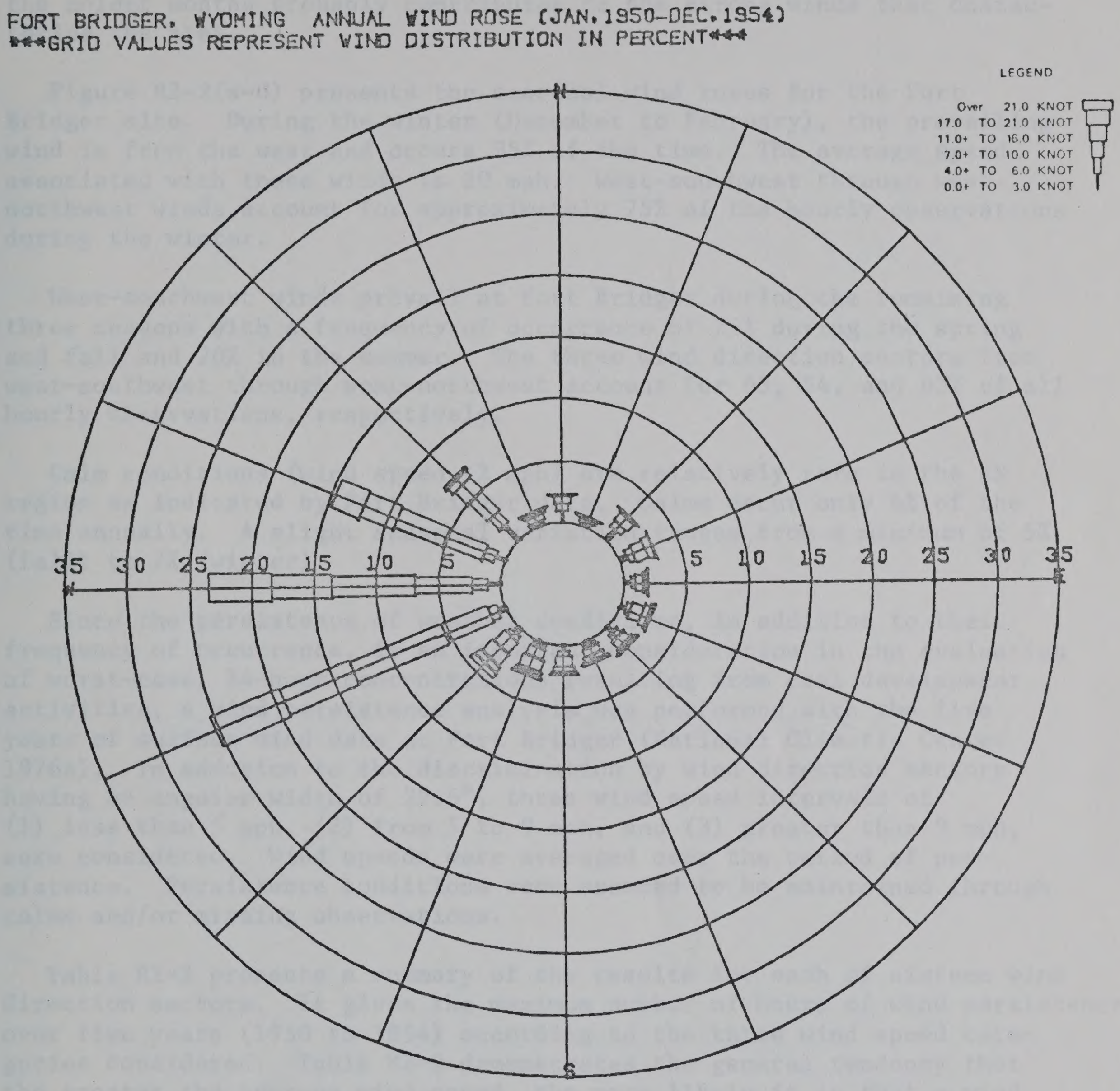

Figure R2-1

Five-Year (1950 to 1954) Annual Average Wind Rose for Fort Bridger

1 knot = 1.15 mph

NOTE: The numbers along the horizontal line through the center represent percentage frequency; the width of the arrows represents wind speed as specified in the upper right hand corner.

In addition, gravitational accelerations resulting from cold dense air spilling over the Wasatch Mountains from the Great Basin High* during the colder months probably contributes to the strong winds that characterize the area.

Figure R2-2(a-d) presents the seasonal wind roses for the Fort Bridger site. During the winter (December to February), the prevailing wind is from the west and occurs 35% of the time. The average speed associated with these winds is 20 mph. West-southwest through west-northwest winds account for approximately 75% of the hourly observations during the winter.

West-southwest winds prevail at Fort Bridger during the remaining three seasons with a frequency of occurrence of 25% during the spring and fall and 20% in the summer. The three wind direction sectors from west-southwest through west-northwest account for 63, 54, and 62% of all hourly observations, respectively.

Calm conditions (wind speed <2 mph) are relatively rare in the ES region as indicated by Fort Bridger data. Calms occur only 6% of the time annually. A slight seasonal variation ranges from a minimum of 5% (fall) to 7% (winter).

Since the persistence of weather conditions, in addition to their frequency of occurrence, is an important consideration in the evaluation of worst-case, 24-hour concentrations resulting from coal development activities, a wind persistence analysis was performed with the five years of surface wind data at Fort Bridger (National Climatic Center 1976a). In addition to the discrimination by wind direction sectors having an angular width of 22.5°, three wind speed intervals of: (1) less than 5 mph, (2) from 5 to 9 mph, and (3) greater than 9 mph, were considered. Wind speeds were averaged over the period of persistence. Persistence conditions were assumed to be maintained through calms and/or missing observations.

Table R2-2 presents a summary of the results for each of sixteen wind direction sectors. It gives the maximum number of hours of wind persistence over five years (1950 to 1954) according to the three wind speed categories considered. Table R2-2 demonstrates the general tendency that the greater the average wind speed, the more likely it is that a wind direction will persist. At Fort Bridger, the maximum periods of persistence are associated with those wind directions also occurring most frequently with west-southwest and west winds showing periods greater than two days of persistence.

Table R2-3 presents an additional summary of wind persistence results but addresses only those wind direction sectors that indicated twelve or more hours of persistence. The data are grouped into annual and seasonal categories.

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*The Great Basin High is a semipermanent cold dome of high pressure that is typically centered near the northwestern Utah/northeastern Nevada border.

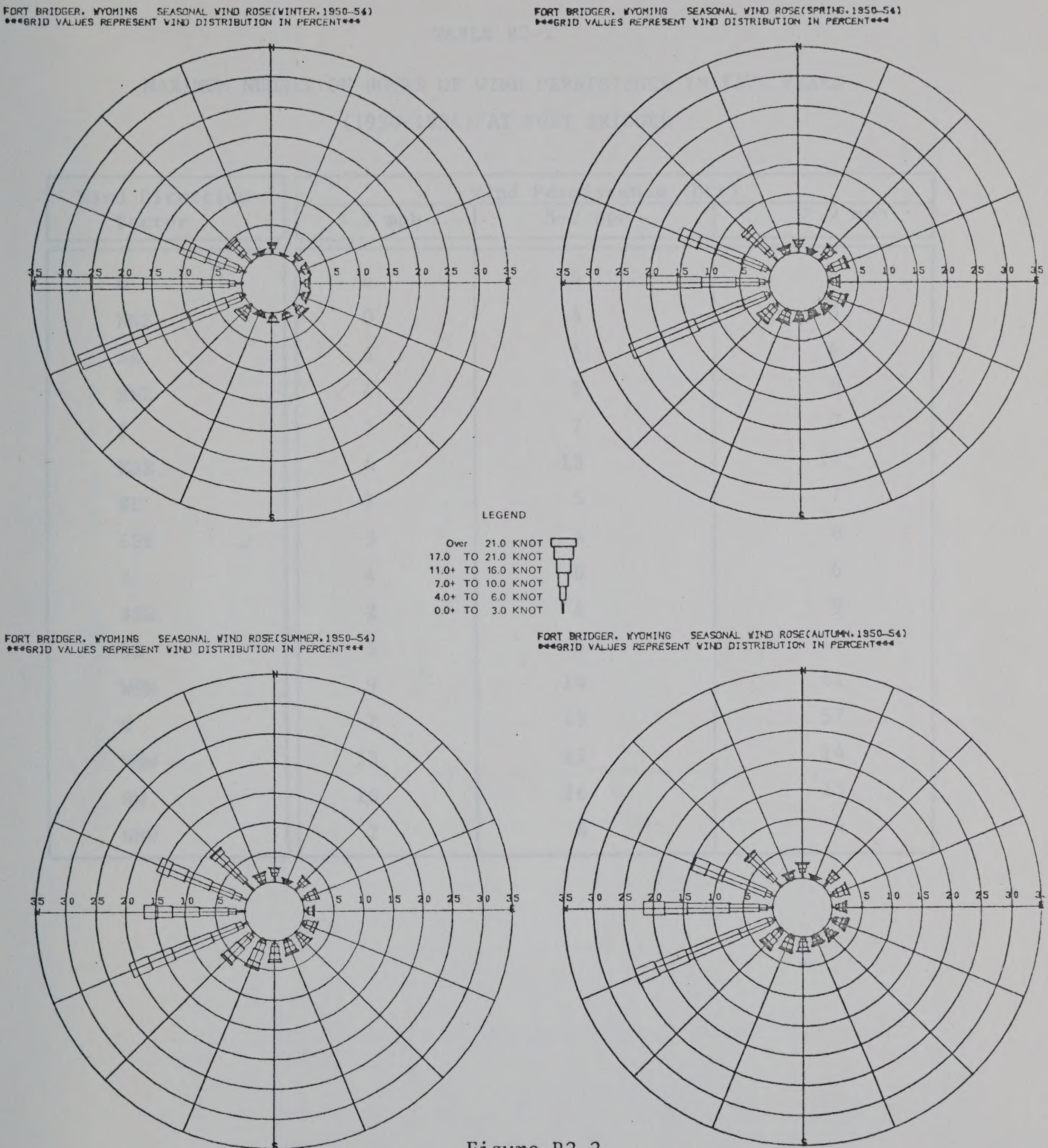

Figure R2-2

Five-Year (1950 to 1954) Seasonal Average Wind Roses for Fort Bridger

1 knot = 1.15 mph

SW Ch.__________
Sec.__________
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TABLE R2-2

MAXIMUM NUMBER OF HOURS OF WIND PERSISTENCE IN FIVE YEARS (1950-1954) AT FORT BRIDGER

Wind Direction Sector	Wind Persistence (hrs)		
	< 5 mph	5-9 mph	> 9 mph
N	6	4	4
NNE	0	4	3
NE	4	6	6
ENE	4	7	6
E	7	7	7
ESE	4	13	14
SE	7	5	7
SSE	3	4	8
S	4	6	6
SSW	2	4	9
SW	5	5	15
WSW	9	14	61
W	7	15	57
WNW	13	11	14
NW	16	16	15
NNW	2	4	4

TABLE R2-3

WIND PERSISTENCE AT FORT BRIDGER (1950-1954)

(hours)

Wind Speed (mph)	Wind Direction	Annual*			Winter			Spring			Summer			Fall		
		Max No. of Hrs.	No. of Periods ≥12	No. of Periods ≥24	Max No. of Hrs.	No. of Periods ≥12	No. of Periods ≥24	Max No. of Hrs.	No. of Periods ≥12	No. of Periods ≥24	Max No. of Hrs.	No. of Periods ≥12	No. of Periods ≥24	Max No. of Hrs.	No. of Periods ≥12	No. of Periods ≥24
>9	ESE	14	1	-	-	-	-	14	1	-	-	-	-	-	-	-
	SW	15	1	-	-	-	-	15	1	-	-	-	-	-	-	-
	WSW	61	100	6	61	42	5	30	28	1	13	7	-	17	23	-
	W	57	53	15	57	45	12	-	-	-	-	-	-	48	8	3
	WNW	14	3	-	13	1	-	14	1	-	-	-	-	12	1	-
	NW	15	22	-	-	-	-	-	1	-	-	-	-	15	1	-
5-9	ESE	13	1	-	-	-	-	13	1	-	-	-	-	-	-	-
	WSW	14	1	-	-	-	-	14	1	-	-	-	-	-	-	-
	W	15	3	-	15	3	-	-	-	-	-	-	-	-	-	-
	NW	16	1	-	16	1	-	-	-	-	-	-	-	-	-	-
<5	ENE	13	1	-	-	-	-	13	1	-	-	-	-	-	-	-
	WNW	13	1	-	-	-	-	-	-	-	-	-	-	13	1	-
	NW	16	2	-	13	1	-	-	-	-	-	-	-	16	1	-

*The values represent the number of times that the wind persisted from a given direction for at least 12 or 24 hours in five years or during the indivudual seasons of those five years.

The table lists the maximum number of hours of persistence, as well as the total number of periods during the five years when 12 or 24 hours or more persistence occurred.

Table R2-3 shows that westerly winds are the most likely to persist in the southwestern region of Wyoming. Again, maximum persistence is associated with strong winds and is most likely to occur in the winter or the transition seasons (the colder months). A west-southwest wind is the only direction showing persistence during the summer months.

Frequency of Wind Direction and Speed in Sweetwater County. The city of Rock Springs, Wyoming, is located in Sweetwater County in the central portion of the ES region, about 65 miles east-northeast of Fort Bridger. The city is situated at an elevation of about 6,400 feet above sea level. The Rock Springs Airport, the wind observation site, is about 9 miles east of the city and 300 feet higher at an elevation of 6,700 feet.

The main ridge line of the Uinta Mountains is located about 80 miles to the southeast of Rock Springs, while the Wind River Range is about 80 miles north of the city.

Figure R2-3 presents the annual wind rose for the Rock Springs Airport. It is also based on five years (1960 to 1964) of hourly wind observations. Similar to Fort Bridger, the prevailing wind direction at Rock Springs is west-southwest, occurring 18% of the time. However, southwest winds are the second most frequent (16%), compared to a westerly direction observed at Fort Bridger. Annually, the three wind direction sectors of southwest through west (214 to 281°) account for 50% of the hourly directional observations at Rock Springs Airport. This aggregate frequency for three sectors is of similar magnitude to the three considered at Fort Bridger, but the directions are rotated 22.5° towards the south.

The annual average wind speed for all directions is 11 mph at Rock Springs, while the 15 mph speed is characteristic of Fort Bridger. For the three predominant directional sectors at Rock Springs, the average annual speed is 14 mph.

Figure R2-4(a-d) presents the seasonal wind roses for Rock Springs for the 1960 to 1964 observation period. West-southwest winds prevail in all seasons, except the summer, when southwest winds predominate. The figures indicate that the three sectors southwest through west together account for a frequency range from 64% (winter) to 36% (summer) of the hourly observations in the respective seasons. In consideration of the average wind speeds for the same three sectors, a range from 15.4 mph (winter) to 11.8 mph (summer) occurs at Rock Springs.

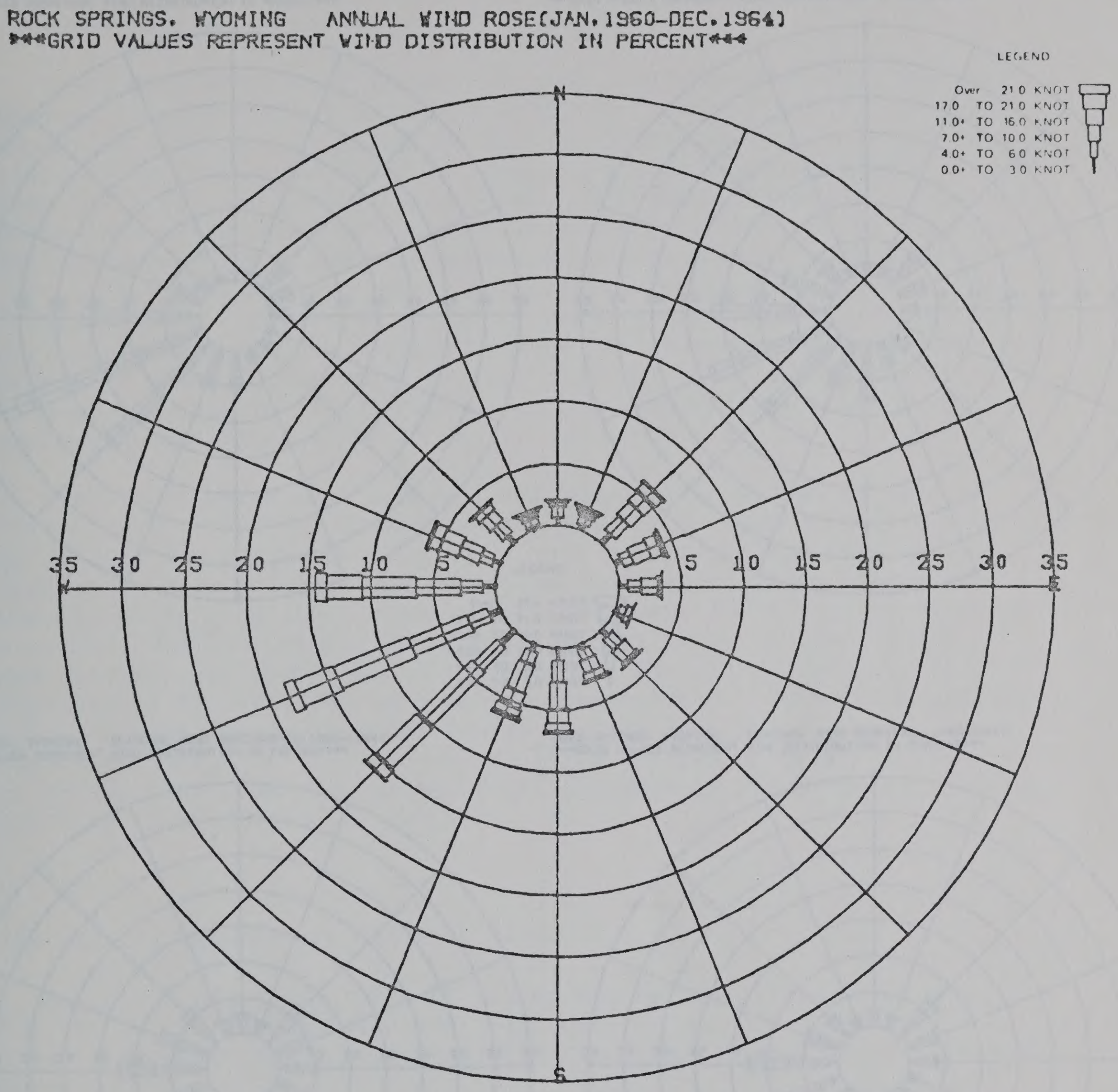

Figure R2-3

Five-Year (1950 to 1954) Annual Average Wind Rose for Rock Springs

1 knot = 1.15 mph

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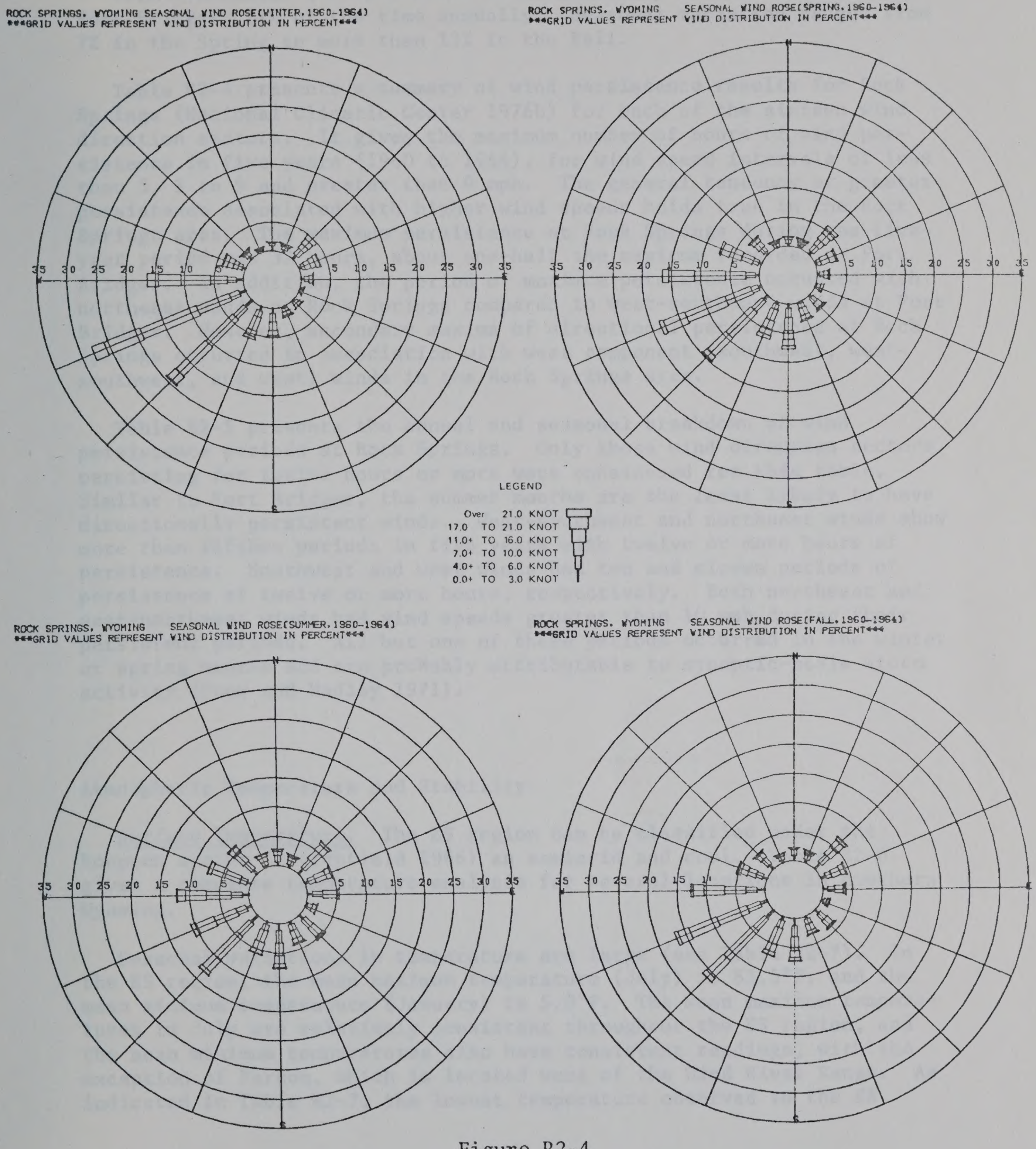

ROCK SPRINGS, WYOMING SEASONAL WIND ROSE(WINTER,1960-1964)
GRID VALUES REPRESENT WIND DISTRIBUTION IN PERCENT

ROCK SPRINGS, WYOMING SEASONAL WIND ROSE(SPRING,1960-1964)
GRID VALUES REPRESENT WIND DISTRIBUTION IN PERCENT

ROCK SPRINGS, WYOMING SEASONAL WIND ROSE(SUMMER,1960-1964)
GRID VALUES REPRESENT WIND DISTRIBUTION IN PERCENT

ROCK SPRINGS, WYOMING SEASONAL WIND ROSE(FALL,1960-1964)
GRID VALUES REPRESENT WIND DISTRIBUTION IN PERCENT

N
35 30 25 20 15 10 5
5 10 15 20 25 30 35
E
S
LEGEND
Over 21.0 KNOT
17.0 TO 21.0 KNOT
11.0+ TO 16.0 KNOT
7.0+ TO 10.0 KNOT
4.0+ TO 6.0 KNOT
0.0+ TO 3.0 KNOT

Figure R2-4

Five-Year (1950 to 1954) Seasonal Average Wind Roses for Rock Springs

1 knot = 1.15 mph

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Calm conditions (<2 mph) occur more frequently at Rock Springs than Fort Bridger, 11% of the time annually. Seasonal variation ranges from 7% in the Spring to more than 13% in the Fall.

Table R2-4 presents a summary of wind persistence results for Rock Springs (National Climatic Center 1976b) for each of the sixteen wind direction sectors. It gives the maximum number of hours of wind persistence in five years (1960 to 1964), for wind speed intervals of less than 5, 5 to 9 and greater than 9 mph. The general tendency of greater persistence associated with higher wind speeds holds true in the Rock Springs area. The maximum persistence at Rock Springs during the five-year period was 32 hours, about one-half the maximum recorded at Fort Bridger. In addition, the period of maximum persistence occurred with northeast winds at Rock Springs compared to west-southwest winds at Fort Bridger. However, secondary maxima of directional persistence at Rock Springs occurred in association with west component (southwest, west-southwest, and west) winds in the Rock Springs area.

Table R2-5 presents the annual and seasonal breakdown of wind persistence periods at Rock Springs. Only those wind direction sectors persisting for twelve hours or more were considered for this table. Similar to Fort Bridger, the summer months are the least likely to have directionally persistent winds. West-southwest and northeast winds show more than fifteen periods in five years with twelve or more hours of persistence. Southwest and west winds had ten and eleven periods of persistence of twelve or more hours, respectively. Both northeast and east-northeast winds had wind speeds greater than 10 mph during their persistent periods. All but one of these periods occurred in the winter or spring months and are probably attributable to synoptic-scale storm activity (Crow and Hadley 1971).

Atmospheric Temperature and Stability

Surface Temperature. The ES region can be classified under the Koeppen system (Critchfield 1966) as semiarid and cool. Table R2-6 gives a complete temperature analysis for several locations in southern Wyoming.

Seasonal variations in temperature are large (see Table R2-7). In the ES region, the mean maximum temperature (July) is 83.5°F, and the mean minimum temperature (January) is 5.0°F. The mean maximum temperatures in July are relatively consistent throughout the ES region, and the mean minimum temperatures also have consistent readings, with the exception of Farson, which is located west of the Wind River Range. As indicated in Table R2-7, the lowest temperature observed in the ES

TABLE R2-4

MAXIMUM NUMBER OF HOURS OF WIND PERSISTENCE IN FIVE YEARS (1960-1964) AT ROCK SPRINGS

Wind Direction Sector	Wind Speed Interval (mph)		
	< 5	5-9	> 9
N	4	4	4
NNE	4	5	10
NE	8	10	32
ENE	6	9	16
E	6	11	9
ESE	6	4	4
SE	5	9	8
SSE	6	6	6
S	13	11	12
SSW	5	4	12
SW	10	16	27
WSW	20	8	22
W	6	9	17
WNW	3	4	15
NW	2	8	7
NNW	3	3	5

TABLE R2-5

WIND PERSISTENCE AT ROCK SPRINGS (1960-1964)

(hours)

Wind Speed mph	Wind Direction	Annual*			Winter			Spring			Summer			Fall		
		Max No. of Hrs	No. of Periods		Max No. of Hrs	No. of Periods		Max No. of Hrs	No. of Periods		Max No. of Hrs	No. of Periods		Max No. of Hrs	No. of Periods	
			≥12	≥24		≥12	≥24		≥12	≥24		≥12	≥24		≥12	≥24
>9	NE	32	15	3	17	5	–	32	4	2	–	–	–	30	6	1
	ENE	16	2	–	16	2	–	–	–	–	–	–	–	–	–	–
	S	12	1	–	–	–	–	12	1	–	–	–	–	–	–	–
	SSW	12	1	–	–	–	–	12	1	–	–	–	–	–	–	–
	SW	27	10	1	23	3	–	14	3	–	13	1	–	27	3	1
	WSW	22	15	–	22	11	–	17	2	–	–	–	–	16	2	–
	W	17	11	–	17	5	–	15	4	–	–	–	–	17	2	–
	WNW	15	2	–	15	1	–	12	1	–	–	–	–	–	–	–
5-9	SW	16	2	–	16	1	–	15	1	–	–	–	–	–	–	–
<5	S	13	1	–	13	1	–	–	–	–	–	–	–	–	–	–
	WSW	20	1	–	–	–	–	–	–	–	–	–	–	20	1	–

*The values represent the number of times that the wind persisted from a given wind direction for at least 12 or 24 hours in five years or during the indivudual seasons of those five years.

TABLE R2-6

TEMPERATURE STATISTICS FOR SOUTHERN WYOMING

Station	El (ft)	Lat	Long.	Yrs.		Temperature (°F)												Annual
						J	F	M	A	M	J	J	A	S	O	N	D	
					Mean Max	27	31	37	48	64	72	81	79	74	60	40	29	54
Afton	6115	42°44'	110°56'	28	Mean	15	17	25	37	48	54	61	59	52	42	27	16	38
					Mean Min	1	5	11	23	30	34	36	35	28	23	15	4	20
					Mean Max	28	34	41	52	63	71	80	78	71	57	43	32	54
Bedford	6325	42°52'	110°54'	30	Mean	16	21	26	37	46	54	61	59	52	42	29	20	39
2 SE					Mean Min	5	7	14	24	32	36	42	41	34	27	17	8	24
					Mean Max	24	29	38	51	62	69	79	78	70	58	40	29	52
Big Piney	6821	42°32'	110°07'	23	Mean	9	12	23	36	45	52	59	56	48	38	22	14	34
					Mean Min	-6	-5	8	21	29	36	39	35	27	18	6	-1	17
					Mean Max	19	27	36	48	62	70	78	76	70	56	37	24	50
Bondurant	6605	42°12'	110°25'	6	Mean	4	12	20	33	45	50	56	54	47	37	22	11	32
					Mean Min	-10	-4	3	17	28	31	33	31	24	18	8	-2	18
					Mean Max	25	28	38	52	64	73	83	82	73	60	42	28	54
Border	6120	42°15'	111°62'	30	Mean	12	15	24	38	48	56	63	61	53	42	28	16	38
3 N					Mean Min	-1	2	11	24	32	38	43	40	32	23	13	3	22
					Mean Max	37	40	46	57	68	80	88	86	75	63	48	39	61
Casper	5195	42°51'	106°16'	41	Mean	26	28	34	45	55	64	72	69	59	48	36	29	47
2 E					Mean Min	16	18	23	31	40	48	55	54	43	34	26	18	34
					Mean Max	33	37	44	56	66	77	87	85	75	61	44	37	58
Casper	5319	42°55'	106°28'	30	Mean	24	27	33	43	53	64	72	70	59	48	35	27	46
W8 AP					Mean Min	14	16	22	31	40	48	57	55	45	35	24	18	34
					Mean Max	32	33	37	48	60	70	76	75	67	55	42	34	52
Centennial	8074	41°18'	106°09'	42	Mean	22	23	27	36	46	55	62	60	53	43	31	25	40
					Mean Min	12	12	16	25	33	41	47	46	38	29	20	15	28
					Mean Max	33	38	46	57	66	76	86	84	74	61	45	37	59
Division Dam	5574	41°14'	108°56'	22	Mean	20	24	32	43	52	60	68	66	57	46	32	24	44
					Mean Min	6	9	19	29	38	44	51	48	40	31	18	11	29
					Mean Max	32	36	43	56	66	76	84	82	73	60	45	35	57
Dixon	6364	41°02'	107°32'	38	Mean	18	22	30	42	50	58	66	64	55	44	30	21	42
					Mean Min	4	8	17	27	33	41	46	45	37	28	16	8	26
					Mean Max	32	34	39	51	62	73	80	80	72	60	43	36	55
Elk Mountain	7109	41°42'	106°25'	12	Mean	21	24	28	38	48	56	63	61	54	44	30	26	41
					Mean Min	10	14	16	24	33	40	45	44	36	29	19	16	27

*Indicates stations in the ES region.

TABLE R2-6 (Continued)

TEMPERATURE STATISTICS FOR SOUTHERN WYOMING

Station	El (ft)	Lat	Long.	Yrs.		Temperature (°F)												Annual
						J	F	M	A	M	J	J	A	S	O	N	D	
Pathfinder Dam	5930	42°28'	106°51'	43	Mean Max	33	36	43	55	66	77	87	85	75	62	45	35	58
					Mean	22	26	32	43	53	63	71	69	59	47	35	26	46
					Mean Min	12	15	21	30	39	48	55	54	44	35	24	16	33
Pavillion	5440	43°15'	108°41'	22	Mean Max	31	38	48	60	70	79	88	86	76	62	43	34	60
					Mean	18	25	34	46	55	63	71	68	59	48	31	23	45
					Mean Min	6	11	20	31	40	47	58	52	43	33	19	11	31
Pinedale	7210	42°52'	109°51'	42	Mean Max	26	31	38	49	61	71	80	77	68	55	40	29	52
					Mean	12	15	23	35	45	54	60	67	49	38	25	15	37
					Mean Min	-3	-1	7	20	27	36	41	37	29	22	11	1	19
Rawlins FAA AP	6736	41°48'	107°12'	30	Mean Max	31	34	41	54	66	77	85	82	71	58	43	32	56
					Mean	22	24	31	41	50	61	67	66	55	45	32	23	43
					Mean Min	12	14	20	28	36	44	52	49	41	31	22	14	30
Riverton	4954	43°01'	108°23'	22	Mean Max	29	37	48	60	70	79	89	87	76	63	44	33	60
					Mean	14	22	33	45	54	62	70	68	58	46	29	19	43
					Mean Min	0	6	18	29	38	46	51	48	40	30	15	5	27
Rock Springs* City	6367	41°35'	109°13'	22	Mean Max	32	37	45	57	66	77	86	84	75	62	45	36	59
					Mean	21	25	33	43	52	61	68	66	58	45	32	25	44
					Mean Min	10	14	21	29	37	44	50	48	40	30	19	13	30
Rock Springs* FAA AP	6741	41°36'	109°04'	28	Mean Max	29	33	41	53	64	74	84	82	72	59	41	33	55
					Mean	19	23	30	41	51	60	68	66	57	45	30	24	43
					Mean Min	8	12	14	28	37	45	53	51	42	32	19	14	30
Sage 4 NW*	6321	41°52'	111°01'	33	Mean Max	29	32	41	54	65	75	86	82	73	60	42	32	56
					Mean	14	18	27	39	47	55	64	61	52	41	27	18	39
					Mean Min	-1	3	13	24	31	36	42	40	31	23	12	3	21
Sand Draw	6060	42°45'	108°11'	6	Mean Max	30	36	40	56	65	73	85	84	74	61	44	36	57
					Mean	18	25	29	44	52	59	70	69	59	48	32	26	44
					Mean Min	7	14	18	31	38	46	54	43	44	35	21	15	32
Saratoga	6786	41°27'	106°48'	35	Mean Max	33	36	42	54	65	75	84	82	73	60	45	36	57
					Mean	20	24	29	40	49	58	66	65	55	44	30	24	42
					Mean Min	8	12	18	27	35	42	48	47	38	28	17	11	27
Seminoe Dam	6838	42°08'	106°53'	23	Mean Max	30	33	40	54	63	73	84	82	72	59	41	34	55
					Mean	21	24	29	41	50	60	68	67	58	46	32	25	42
					Mean Min	12	14	19	29	37	46	54	53	43	34	26	16	32
South Pass City	7805	42°28'	104°48'	21	Mean Max	25	27	32	45	57	66	76	74	65	53	37	28	49
					Mean	12	15	20	33	42	50	58	56	47	38	24	16	34
					Mean Min	-1	2	8	20	28	34	39	27	30	22	10	4	20
Wamsutter 1 N	6815	41°41'	107°59'	23	Mean Max	29	33	41	55	66	77	85	83	73	59	42	31	56
					Mean	18	21	29	41	51	59	77	75	56	44	29	14	43
					Mean Min	7	11	18	27	36	42	48	47	38	28	17	7	26

*Indicates stations in the ES region

Sources: Temperature Probabilities in Wyoming (Becker and Alyea 1964b); Climatic Summary of U.S., 1931 through 1952 and 1951 through 1960 (U.S. Department of Commerce).

TABLE R2-6 (Continued)

TEMPERATURE STATISTICS FOR SOUTHERN WYOMING

Station	El (ft)	Lat	Long.	Yrs.		Temperature (°F)												
						J	F	M	A	M	J	J	A	S	O	N	D	Annual
Encampment 10 ESE	7387	41°11'	106°37'	32	Mean Max	34	36	41	54	64	74	82	80	73	62	45	37	57
					Mean	22	24	29	40	48	57	65	64	55	45	32	26	41
					Mean Min	10	12	17	25	34	41	47	46	38	29	18	14	27
Evanston* 1 E	6860	41°16'	110°57'	21	Mean Max	30	33	40	52	63	71	81	80	72	59	43	34	55
					Mean	17	21	27	39	47	54	62	61	53	43	28	22	40
					Mean Min	4	8	14	25	32	38	44	42	34	26	14	9	24
Farson	6600	42°07'	109°25'	18	Mean Max	25	30	39	54	66	75	84	81	72	60	42	30	55
					Mean	9	14	24	39	49	57	64	61	53	41	25	15	38
					Mean Min	-8	-3	10	23	31	38	44	41	33	22	8	-1	22
Fort Bridger* CAA AP	7034	41°23'	110°25'	12	Mean Max	28	31	37	51	62	70	82	80	72	57	40	32	54
					Mean	18	21	27	40	48	56	66	65	57	45	30	23	41
					Mean Min	8	11	17	28	35	41	50	49	41	32	19	14	29
Fort Washakie 2 S	5670	43°00'	108°53'	28	Mean Max	36	41	47	58	67	76	85	84	75	63	47	38	60
					Mean	22	26	32	44	53	60	67	66	57	46	33	25	44
					Mean Min	6	9	16	27	36	44	48	47	38	29	17	9	27
Fox Park	9060	41°05'	106°09'	38	Mean Max	27	28	34	43	53	65	72	70	62	51	37	28	48
					Mean	15	16	22	32	39	48	55	54	45	36	25	18	34
					Mean Min	4	5	9	18	25	33	37	36	28	23	12	6	20
Green River*	6109	41°32'	109°29'	21	Mean Max	32	37	46	59	69	79	88	86	76	63	46	36	60
					Mean	19	24	33	44	53	62	69	68	58	46	32	23	44
					Mean Min	6	10	19	29	37	44	51	49	39	29	17	11	28
Kemmerer*	6960	41°47'	110°32'	30	Mean Max	29	33	38	53	64	73	82	80	71	59	41	34	55
					Mean	17	20	27	39	48	56	63	61	53	43	29	22	40
					Mean Min	5	7	15	24	32	38	44	42	35	25	15	11	24
Kendall	7600	43°09'	110°00'	17	Mean Max	25	28	34	46	57	66	75	74	66	55	38	28	49
					Mean	12	14	20	32	42	50	57	55	48	39	24	16	34
					Mean Min	-2	0	6	19	28	34	39	37	30	23	10	3	19
Lander WB AP	5563	42°49'	108°44'	30	Mean Max	31	36	45	56	66	76	86	84	73	60	42	35	58
					Mean	19	24	32	44	52	62	71	68	59	47	31	23	44
					Mean Min	8	12	20	21	40	48	55	54	44	34	18	12	30
Leo 6 SW	6000	42°12'	106°50'	18	Mean Max	34	38	48	58	68	77	86	83	76	63	46	38	59
					Mean	23	26	33	43	52	61	68	66	57	45	34	28	45
					Mean Min	12	14	20	29	36	44	50	48	40	32	21	17	30
Medicine Bow	6564	41°54'	106°12'	5	Mean Max	28	34	39	55	64	74	82	80	72	60	42	33	55
					Mean	18	23	28	41	49	58	64	62	55	44	30	24	41
					Mean Min	7	12	16	26	35	42	47	44	37	27	18	14	27
Midwest	4850	43°26'	106°16'	22	Mean Max	36	40	47	60	70	80	91	89	78	66	48	39	62
					Mean	23	27	34	45	55	64	73	71	61	50	35	28	47
					Mean Min	11	14	21	31	40	48	55	53	43	34	22	16	32

*Indicates stations in the ES region.

region was -34°F at Evanston, and the highest temperature recorded of 97°F occurred at both Rock Springs and Kemmerer.

Maps R2-2 to R2-5 give an analysis of the mean minimum and mean maximum temperatures for January and July. Using these data, the average diurnal variations for these two months was computed (Table R2-8). The average diurnal variation for January is 24.5°F; for July it is 36.0°F. The combination of intense solar heating and strong radiational cooling associated with lighter winds in summer than winter could explain greater diurnal variation of temperature in the warmer months.

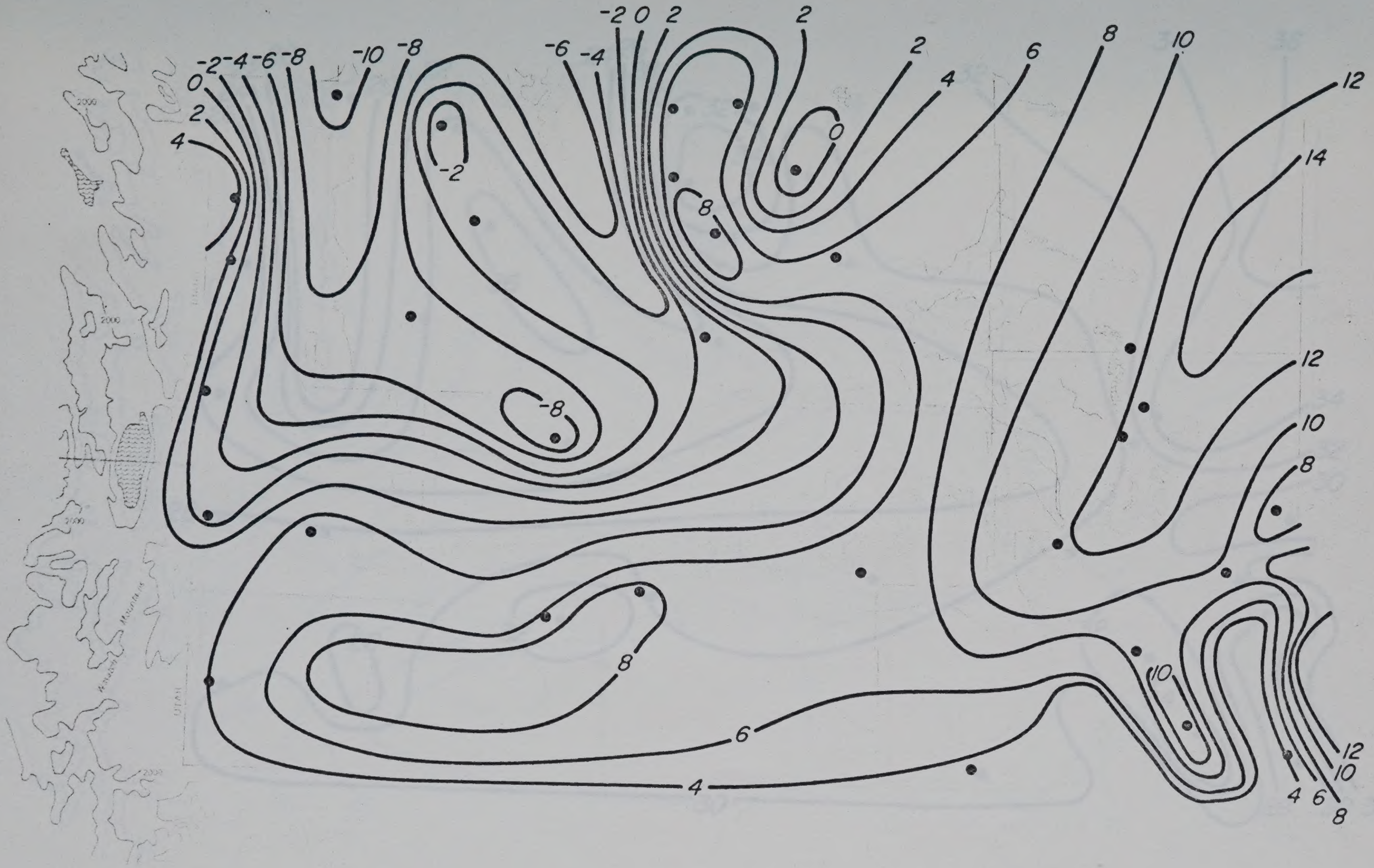
A probability study of temperature is given in Figures R2-5, R2-6, and R2-7 for Evanston, Farson, and Green River. Data from Farson are presented because of its proximity to the ES region, even though Farson is not directly within it. These graphs show that the summer months have 25% and 75% probability curves that are closer to the mean (50%) curve than those of the winter months, suggesting that the summer high means depend more on radiative heat transfer, which is relatively constant. than on air mass changes that influence the diurnal variation of temperature in the winter.

Freeze Data. Freezes are classified into three general types: light, moderate, and severe. A temperature of 30° to 34°F constitutes a light freeze; 25° to 28°F a moderate freeze; and 21° to 24°F a severe freeze (Becker, Alyea, and Eppson 1961). A light freeze causes severe damage to tender plants, such as beans. A moderate freeze can damage more hardy fruit trees or potatoes that a light freeze would not affect. A severe freeze kills the most hardy annual plants and causes perennials to become dormant. Tables R2-9 and R2-10 give the average dates and a probability study of the last freeze in spring and the first freeze in fall at selected stations for temperature threshold levels that generally encompass these freeze categories. Table R2-11 gives the average number of freeze-free days (with respect to the four threshold levels cited) for the selected stations.

The growing season is defined to be the period when mean daily temperatures are above 40°F (Trelease et al. 1970). Table R2-12 gives the average growing season for grass (pasture) for selected stations. Map R2-6 shows that, in the ES region, the growing season for grass is generally greater than 190 days per year. Kemmerer's average growing season is 187 days, and Green River's is 207 days. Assuming that the growing season for grass is generally representative of native flora in the proposed mining regions, this range of dates suggests the period when active vegetation reclamation could be pursued.

Vertical Temperature Profile. It is necessary to understand the thermal structure of the atmosphere to evaluate the impact of emissions. The stability of the atmosphere regulates its ability to disperse pollutants. Stability conditions can be generally classified into three broad categories: unstable, neutral, and stable.

701210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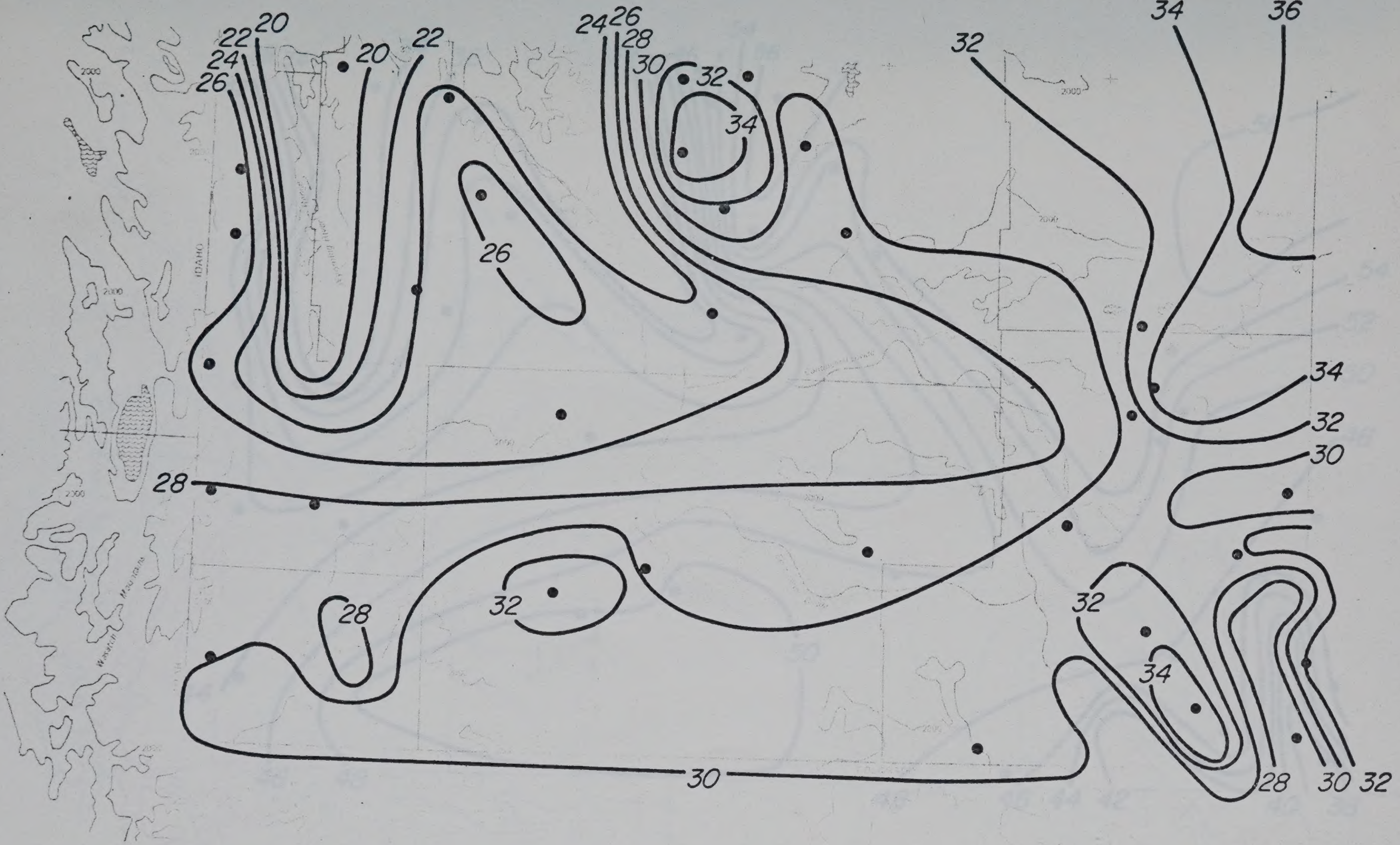
Map R2-2

Mean Minimum Temperature for January
(See Map R2-1 for names of monitoring sites.)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Map R2-3

Mean Maximum Temperature for January
(See Map R2-1 for names of monitoring sites.)

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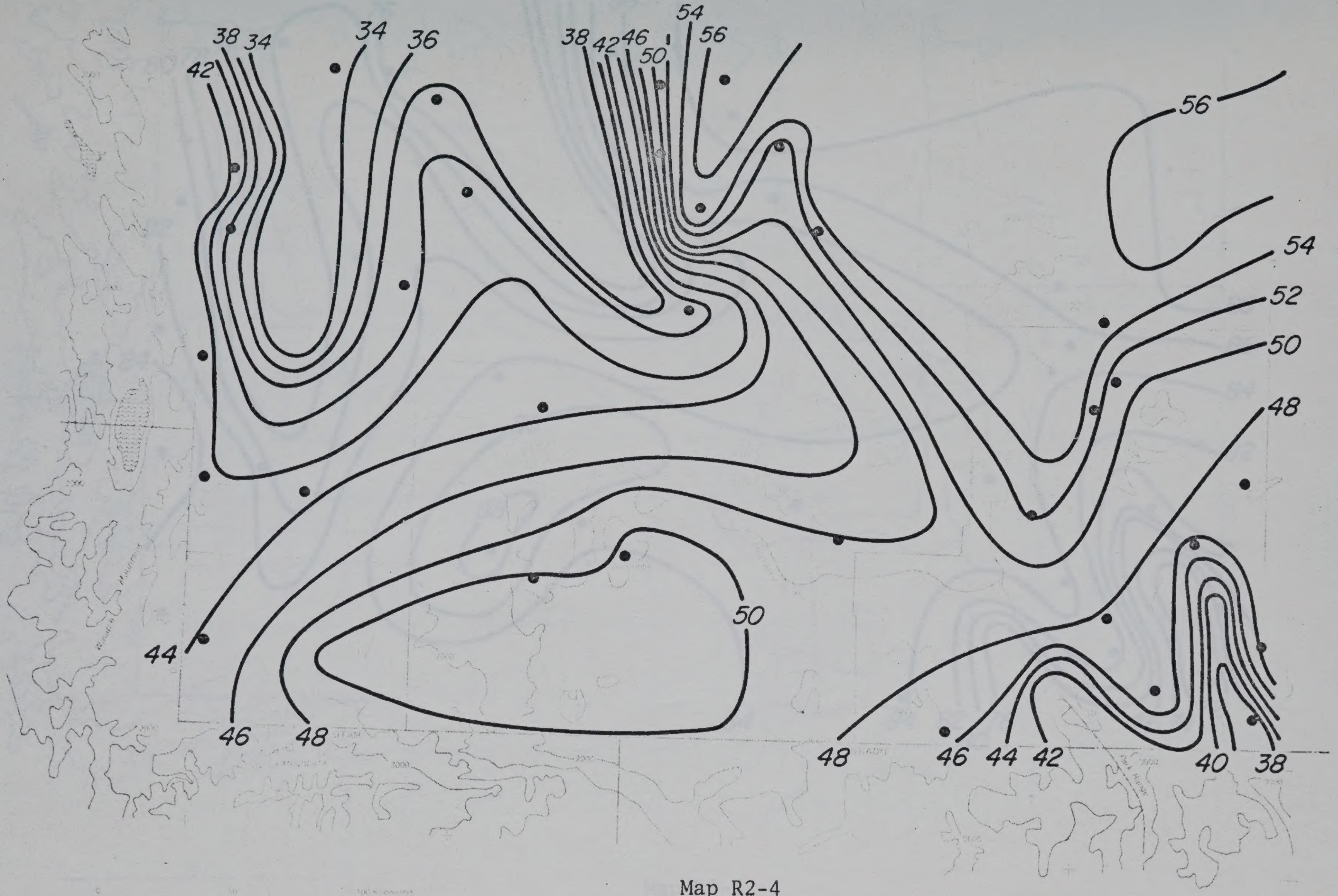
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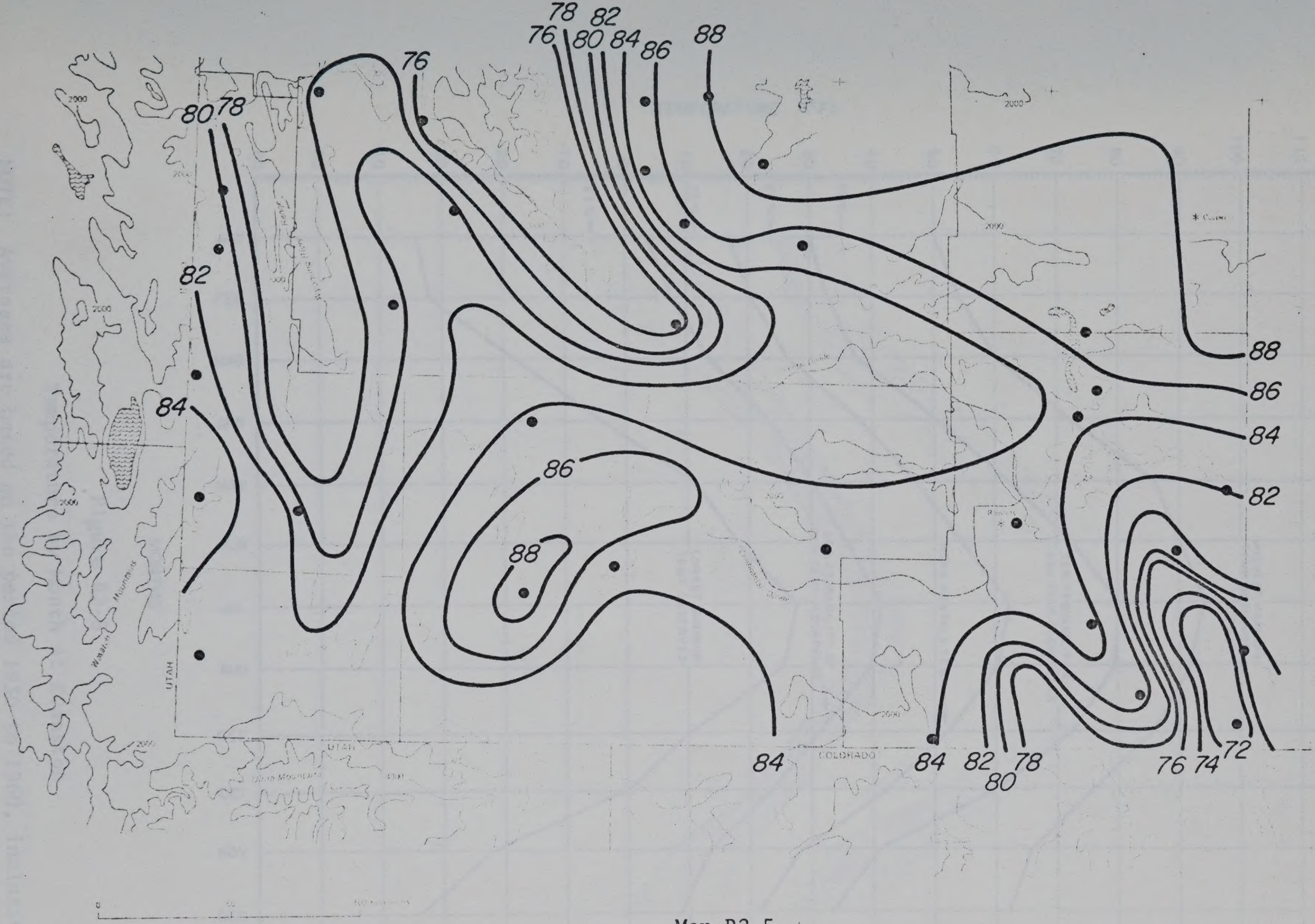
Map R2-4

Mean Minimum Temperature for July
(See Map R2-1 for names of monitoring sites.)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80
78
76
74
72
UTAH
COLORADO
2000
Wasatch Mountains
Uinta Mountains
0
50
100

Map R2-5

Mean Maximum Temperature for July
(See Map R2-1 for names of monitoring sites.)

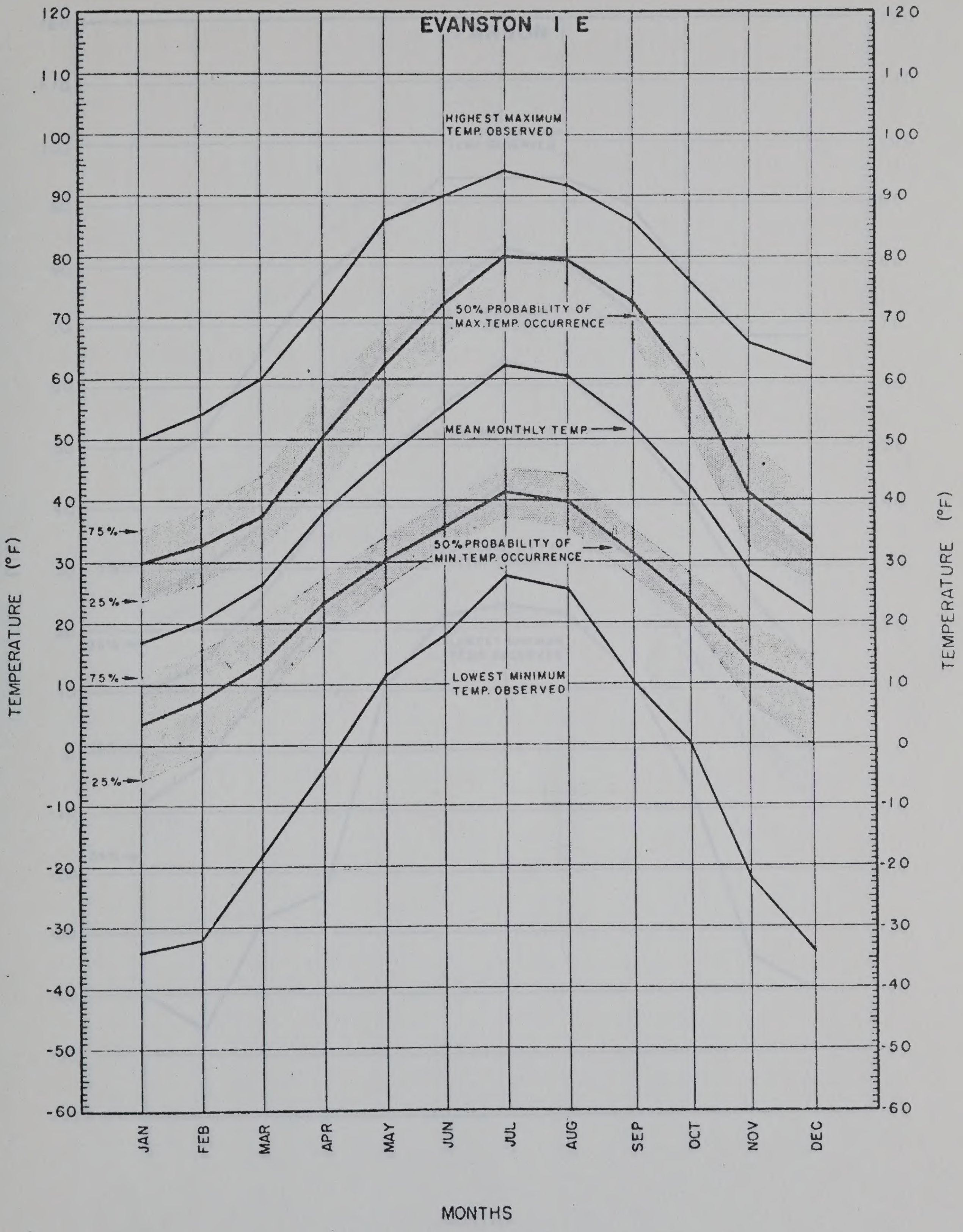


Figure R2-5

Temperature by Month at Evanston

NOTE: Averages are based on the period 1930 to 1960, inclusive.

Source: Becker and Alyea 1964b

701263

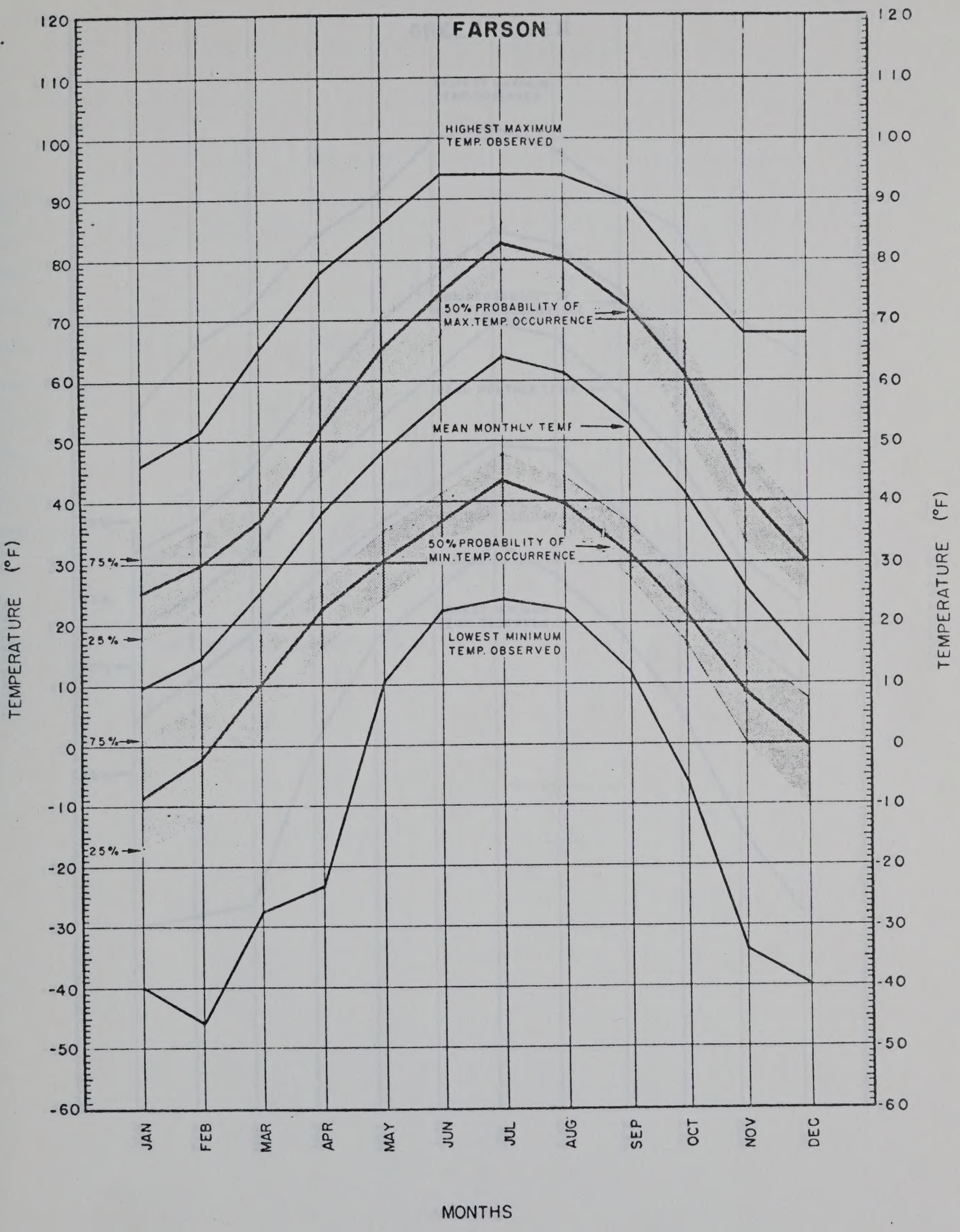


Figure R2-6

Temperature by Month at Farson

NOTE: Averages based on the period 1930 to 1960, inclusive.

Source: Becker and Alyea 1964b

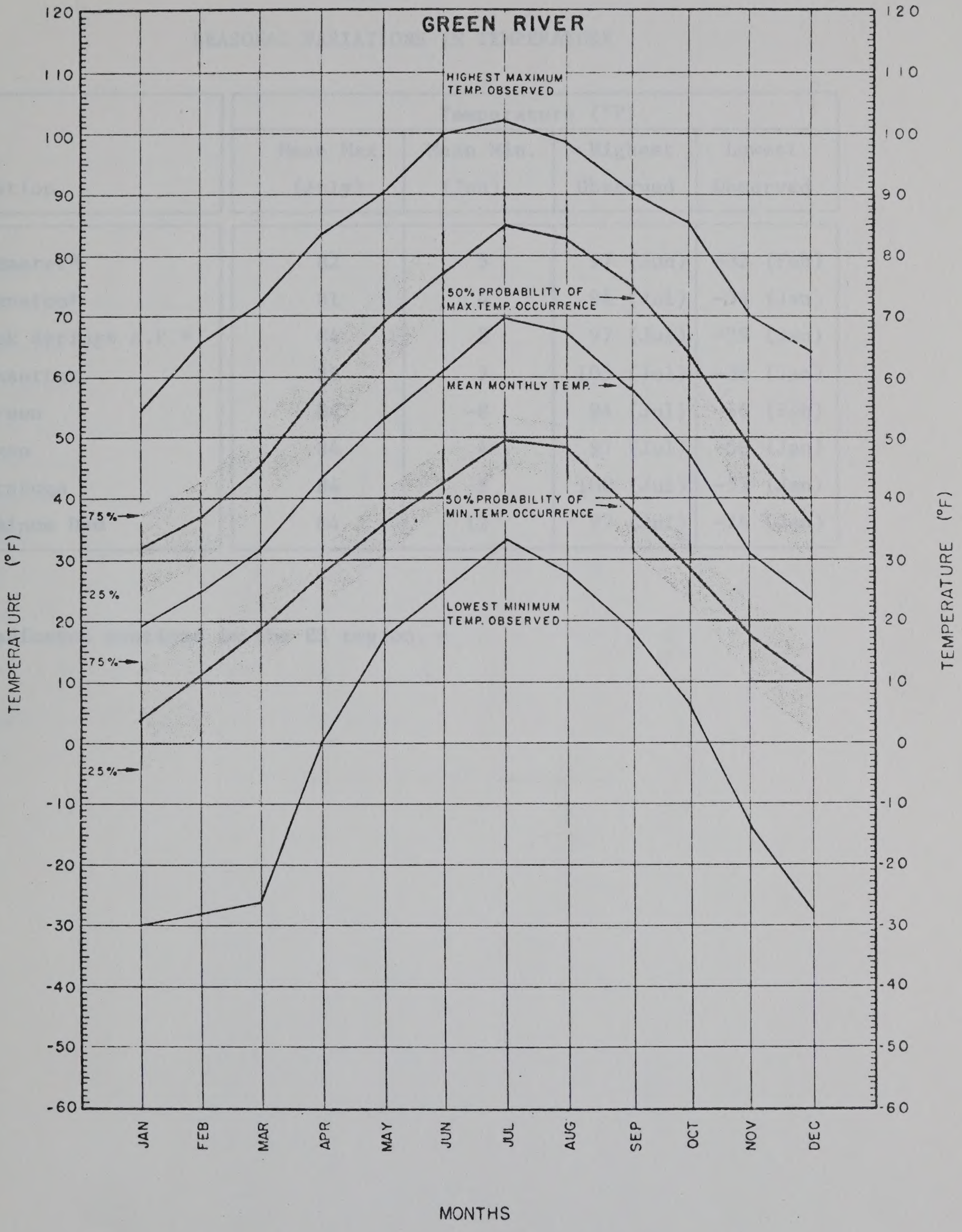


Figure R2-7

Temperature by Month at Green River

NOTE: Averages are based on the period 1930 to 1960, inclusive.

Source: Becker and Alyea 1964b

701261

TABLE R2-7

SEASONAL VARIATIONS IN TEMPERATURE

Station	Temperature (°F)			
	Mean Max. (July)	Mean Min. (Jan)	Highest Observed	Lowest Observed
Kemmerer*	82	5	97 (Jun)	-32 (Feb)
Evanston*	81	4	94 (Jul)	-34 (Jan)
Rock Springs A.P.*	84	8	97 (Jul)	-29 (Jan)
Wamsutter	85	7	105 (Jul)	-38 (Jan)
Farson	84	-8	94 (Jul)	-46 (Feb)
Dixon	84	4	97 (Jul)	-50 (Jan)
Saratoga	84	8	100 (Jul)	-55 (Jan)
Seminoe Dam	84	12	97 (Jul)	-26 (Jan)

*Indicates stations in the ES region.

TABLE R2-8

DIURNAL VARIATIONS IN TEMPERATURE

Station	Temperature (°F)					
	Mean Max.		Mean Min.		Diurnal Variation	
	Jan	Jul	Jan	Jul	Jan	Jul
Kemmerer*	29	82	5	44	24	38
Evanston*	30	81	4	44	26	37
Rock Springs A.P.*	29	84	8	53	21	31
Wamsutter	29	85	7	48	22	37
Farson	25	84	-8	44	33	40
Dixon	32	84	4	46	28	38
Saratoga	33	84	8	48	25	36
Seminoe Dam	30	84	12	54	18	30

*Indicates stations in the ES region.

TABLE R2-9

AVERAGE DATES OF LAST FREEZE IN SPRING

Station	Elevation (feet)	32°F	28°F	24°F	20°F
Afton	6115	X	X	5/23	5/8
Casper A.P.	5319	5/18	5/5	4/24	4/13
Diversion Dam	5574	5/24	5/7	4/26	4/17
Dixon	6364	6/10	5/28	5/13	4/29
Evanston 1E*	6860	X	6/9	5/19	5/4
Farson	6591	X	6/6	5/23	5/8
Green River*	6089	6/3	5/17	5/1	4/18
Kemmerer*	6954	X	5/29	5/18	4/24
Leo 6 SW	6000	6/7	5/20	5/3	4/23
Pinedale	7190	X	X	5/25	5/12
Riverton	4954	5/22	5/9	4/26	4/17
Saratoga	6786	6/10	5/26	5/14	4/29
South Pass City	7805	X	X	X	5/23

X Indicates that threshold temperature or lower can occur at any time.

* Indicates station in the ES region.

The mean date of the last spring freeze represents probability at the 50% level; that is, there is a 50-50 chance that the indicated freeze intensity will occur after the mean freeze date.

Number of days to add to, or subtract from the average spring freeze dates for probabilities other than 50%:

Probability	40%	30%	20%	10%	5%
Add this number of days	4	7	11	17	22

Probability	60%	70%	80%	90%	95%
Subtract this number of days	4	7	11	17	22

Source: Probabilities of Freeze in Wyoming (Becker, Alyea, and Eppson 1961).

TABLE R2-10

AVERAGE DATES OF FIRST FREEZE IN FALL

Station	Elevation (feet)	32°F	28°F	24°F	20°F
Afton	6115	X	X	9/11	9/24
Casper A.P.	5319	9/25	10/2	10/15	10/22
Diversion Dam	5574	9/18	9/27	10/9	10/17
Dixon	6364	9/1	9/19	9/30	10/13
Evanston 1E*	6860	X	9/8	9/25	10/7
Farson	6591	X	8/30	9/21	9/27
Green River*	6089	9/12	9/26	10/7	10/18
Kemmerer*	6954	X	9/17	9/26	10/6
Leo 6 SW	6000	8/30	9/26	10/3	10/14
Pinedale	7190	X	X	9/10	9/20
Riverton	4954	9/20	9/28	10/7	10/19
Saratoga	6786	8/29	9/16	9/27	10/9
South Pass City	7805	X	X	X	9/13

X Indicates threshold temperature or lower can occur at any time.
* Indicates stations in the ES region.

The mean date of the first fall freeze represents probability at the 50% level, that is, there is a 50-50 chance that the indicated freeze intensity will occur before the mean freeze date.

Number of days to subtract from, or add to, the average fall freeze dates for probabilities other than 50%:

Probability	40%	30%	20%	10%	5%
Subtract this number of days	4	7	12	18	23

Probability	60%	70%	80%	90%	95%
Add this number of days	4	7	12	18	23

Source: Probabilities of Freeze in Wyoming (Becker, Alyea, and Eppson 1961).

TABLE R2-11

AVERAGE NUMBER OF DAYS BETWEEN THE LAST SPRING OCCURRENCE AND THE FIRST FALL OCCURRENCE OF INDICATED TEMPERATURE

Station	Years	32°F	28°F	24°F	20°F
Afton	29	18	54	110	138
Casper A.P.	29	130	150	174	192
Diversion Dam	30	117	143	165	183
Dixon	29	83	114	141	167
Evanston 1E*	44	49	95	131	158
Farson	39	59	89	123	144
Green River*	43	101	132	159	183
Kemmerer*	17	60	111	131	165
Leo 6SW	20	84	129	153	172
Pinedale	20	34	69	108	131
Riverton	29	121	142	164	185
Saratoga	30	80	112	137	162
South Pass City	30	11	38	76	113

*Indicates station in the ES region.

Source: Probabilities of Freeze in Wyoming (Becker, Alyea, and Eppson 1961).

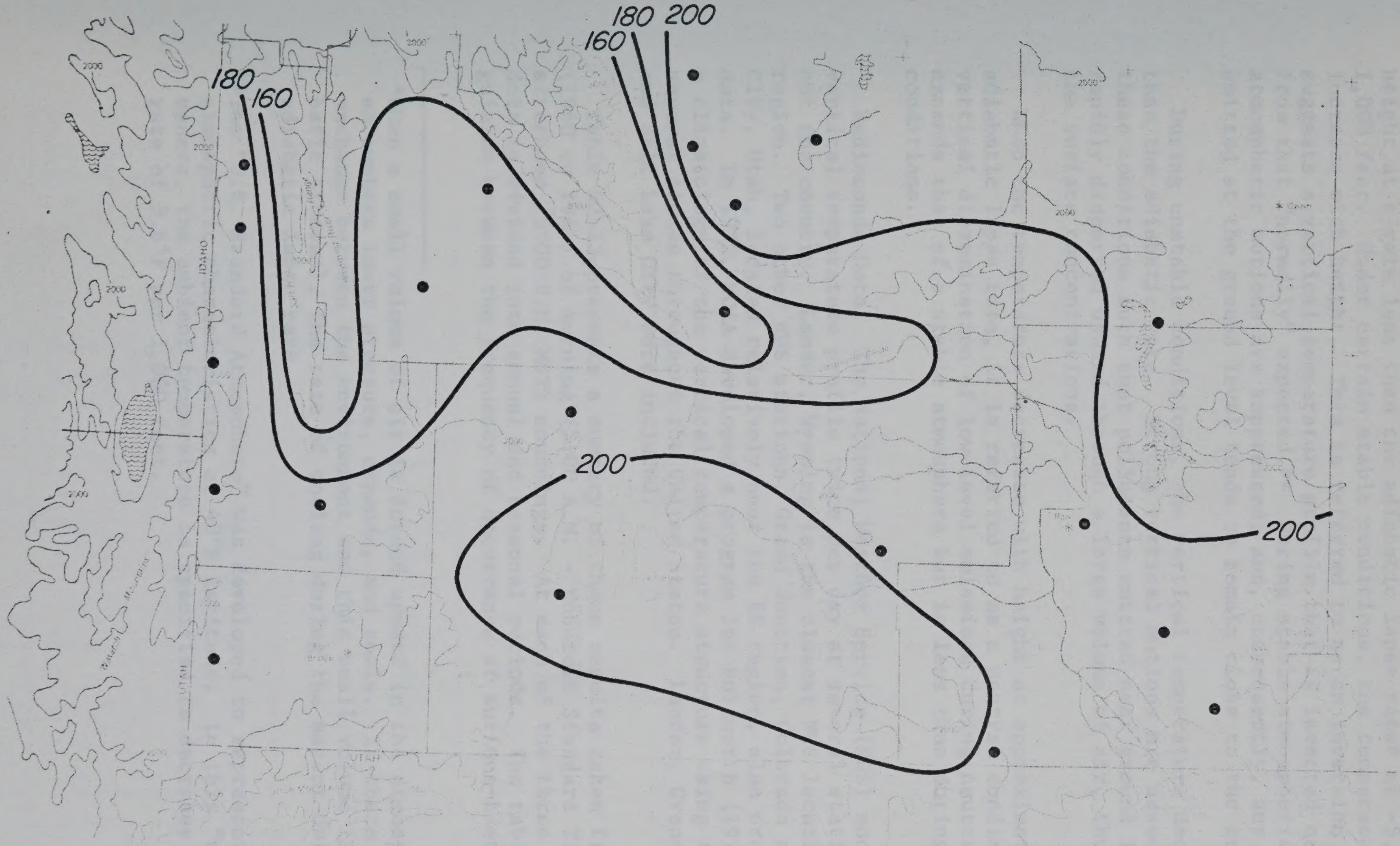
TABLE R2-12

GROWING SEASON FOR GRASS

Station	County	Normal Date of 40° Mean Daily Temp		Length of Growing Season
		Spring	Fall	
Afton	Lincoln	4/21	10/23	185
Bedford 2SE	Lincoln	4/21	10/24	186
Big Piney	Sublette	4/25	10/10	168
Border 3N*	Lincoln	4/17	10/23	189
Casper AP	Natrona	4/8	11/2	208
Diversion Dam	Fremont	4/7	10/30	206
Dixon	Carbon	4/9	10/26	200
Encampment 10ESE	Carbon	4/16	10/28	195
Evanston 1E*	Uinta	4/19	10/23	189
Farson	Sweetwater	4/16	10/19	186
Ft. Washakie 2S	Fremont	4/5	10/29	207
Green River*	Sweetwater	4/5	10/29	207
Kemmerer*	Lincoln	4/18	10/22	187
Lander AP	Fremont	4/7	10/30	206
Pathfinder Dam	Natrona	4/6	11/2	210
Pinedale	Sublette	5/2	10/13	164
Rawlins AP	Carbon	4/12	10/28	199
Riverton	Fremont	4/3	10/28	208
Sage 4NW*	Lincoln	4/18	10/20	185
Saratoga	Carbon	4/15	10/26	194
South Pass City	Fremont	5/8	10/8	153
Wamsutter	Sweetwater	4/11	10/25	197

*Indicates station in the ES region.

Source: Water Resources Research Institute (Trelease et al. 1970).


180
200
160
180
160
200
200
IDAHO
UTAH
UTAH
2000

Map R2-6

Growing Season for Grass
(See Map R2-1 for names of monitoring sites.)

Under stable atmospheric conditions, air temperature decreases with height at a rate less than the adiabatic lapse rate* of -5.4°F per 1,000 feet. Under certain stable conditions, the temperature will increase with height. This is referred to as an inversion condition and suggests a vertical temperature profile that is inverted or reversed from that "normally" expected.** During stable atmospheric conditions, atmospheric motions are suppressed; and, consequently, any pollutant emitted at the ground level tends to remain close to the ground.

During unstable conditions, the vertical temperature decreases faster than the adiabatic rate. Strong vertical motions are associated with these conditions such that pollutants emitted near ground level are rapidly dispersed upward through a large volume of air, thus minimizing the surface concentrations.

When the temperature decreases with height at approximately the adiabatic lapse rate, it is referred to as a neutral condition. The vertical dissemination of low-level emissions during neutral conditions exceeds that of a stable atmosphere but is less than during unstable conditions.

Radiosonde Data. The National Weather Service (NWS) monitors the vertical temperature profile twice per day at several stations throughout the country. Lander, Wyoming is the closest NWS location to the ES region. Two other NWS stations, Grand Junction, Colorado and Salt Lake City, Utah, located relatively near the ES region, also provide these data. In 1972, NOAA developed a program for Holzworth (1974) to prepare a climatology of the vertical temperature structure using these data for several cities throughout the United States. Lander, Grand Junction, and Salt Lake City were included.

Table R2-13 presents a summary of these results taken from five years (1960 to 1964) of morning (5:00 A.M. - Mountain Standard Time [MST]) and afternoon (5:00 P.M. MST) soundings. At each of the three NWS sites, the data is divided into annual and seasonal periods. The table distinguishes between the frequency of occurrence of surface-based inversions,

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*When a small volume of air is forced upward in the atmosphere, it encounters lower pressure, expands, and cools. If there is no heat exchange between the environment and this small volume (i.e., an adia batic process), the rate of cooling during the ascent defines the dry adiabatic lapse rate.

**The "U.S. Standard Atmosphere" was developed to represent average atmospheric characteristics at 40°N latitude. In this "normal atmosphere, the ambient temperature is specified to decrease a constant rate of 3.6°F per 1,000 feet.

TABLE R2-13

FIVE YEAR (1960-1964) SUMMARY OF RADIOSONDE DATA FROM THREE NWS STATIONS PROXIMATE TO SOUTHERN WYOMING

Cumulative Frequency (%) of Surface Inversion Depths, Differential Frequency (%) of Upper-Level Inversion Bases

Time (MST)	Radiosonde Site Location	Period	>1640ft	>820ft	>328ft	All	All	≤2461ft	461-4921ft	>4921ft	Temp Gradient Below			No Inversion			
														Temp	Gradient		<100m
											A	B	C	All	A	B	C
5:00 A.	Lander, Wyo	W	24.7	43.4	80.1	87.4	6.0	3.1	1.1	1.8	0.7	5.3	-	6.0	1.1	5.1	0.4
		S	4.7	18.5	70.7	77.1	8.3	3.1	2.6	2.7	1.5	6.7	-	14.6	3.3	10.7	0.6
		S	6.2	24.7	88.9	89.1	3.9	1.1	2.4	0.4	-	3.7	0.2	7.0	1.3	5.6	-
		F	16.2	31.9	79.2	84.8	6.9	2.2	2.4	1.5	0.7	5.0	0.4	9.0	2.2	5.1	0.6
		A	14.6	29.5	79.7	84.6	6.0	2.3	2.1	1.6	0.7	5.2	0.2	9.3	2.0	6.9	0.5
5:00 A.	Grand Junction, Colorado	W	26.3	45.6	72.8	84.6	6.6	4.0	1.8	0.8	1.3	4.9	0.4	8.7	2.4	6.3	-
		S	5.0	20.6	61.7	78.0	3.2	0.8	0.6	1.8	0.7	2.7	-	18.7	3.7	14.3	-
		S	3.8	19.1	82.2	86.3	1.8	0.8	0.4	0.6	0.2	1.7	-	11.8	3.3	8.3	0.2
		F	9.5	29.7	75.5	87.1	2.8	0.8	0.9	1.1	0.4	2.4	-	10.8	1.6	8.3	0.2
		A	11.0	28.6	73.0	84.0	3.7	0.8	0.9	1.0	0.7	2.9	0.1	12.3	2.8	9.3	0.3
5:00 A.	Salt Lake City, Utah	W	23.6	42.7	66.6	78.7	13.5	9.9	0.8	2.7	3.5	9.3	0.6	7.8	2.7	4.4	0.6
		S	3.5	24.3	63.5	76.5	5.0	2.5	0.2	2.4	0.7	4.2	0.2	18.5	3.9	12.9	1.8
		S	6.3	40.3	81.3	90.4	2.1	2.1	-	-	0.9	1.1	0.2	7.5	2.2	5.3	-
		F	14.3	45.8	76.9	87.9	5.1	2.6	0.7	1.7	1.5	3.4	-	7.0	2.2	4.6	0.2
		A	11.9	38.2	71.2	83.4	6.4	4.2	0.4	1.7	1.6	4.5	0.3	10.2	2.7	6.8	0.7
5:00 P.	Lander, Wyo.	W	5.4	13.6	31.2	32.8	33.7	21.4	7.4	5.0	2.9	22.2	8.6	33.5	3.1	22.2	8.2
		S	-	0.4	1.5	1.5	23.9	5.5	6.1	12.4	-	20.9	3.0	74.6	0.4	29.1	45.0
		S	-	-	2.4	2.4	4.1	0.8	1.8	1.6	-	3.2	0.9	93.5	0.4	24.6	68.4
		F	1.0	3.1	7.5	8.1	32.4	12.3	8.8	11.2	1.5	27.1	3.8	59.5	1.3	18.0	40.1
		A	1.9	4.6	10.9	11.1	23.5	9.9	6.0	7.5	1.1	18.3	4.1	65.4	1.3	23.5	40.6
5:00 P.	Grand Junction, Colorado	W	4.4	5.7	8.8	11.5	47.3	25.0	10.0	12.4	4.0	40.0	3.3	41.2	2.4	31.2	7.5
		S	-	0.6	1.0	2.0	11.1	1.4	1.1	8.7	-	10.4	0.7	86.9	1.3	54.7	30.9
		S	-	-	0.6	1.1	2.2	1.0	-	1.2	-	1.9	0.2	96.7	0.4	47.0	49.3
		F	-	0.2	0.8	3.3	19.8	6.0	3.4	10.4	0.4	18.6	0.7	76.9	1.8	52.6	22.5
		A	1.3	1.8	3.0	4.5	20.0	8.2	3.6	8.2	1.1	17.7	1.2	75.5	1.5	46.4	27.6
5:00 P.	Salt Lake City,	W	2.8	5.2	9.3	10.4	54.6	26.2	10.2	18.4	4.4	44.2	5.9	35.0	4.0	17.5	13.5
		S	-	0.2	2.6	3.3	16.3	2.6	1.7	12.2	0.2	15.3	0.9	80.4	0.9	20.0	58.2
		S	-	-	0.9	0.9	3.5	0.4	0.4	2.6	-	3.0	0.4	95.6	0.2	7.9	82.6
		F	-	0.6	2.9	4.0	29.4	9.0	5.1	15.4	0.9	26.2	2.4	66.6	1.5	18.5	46.6
		A	0.8	1.7	4.2	4.6	25.9	9.3	4.3	12.1	1.4	22.2	2.4	69.5	1.6	16.0	51.8

Temp Gradient: A = 0.0 to -4.39°F per 1,000 ft; B = -4.39 to -6.59°F per 1,000 ft; C = < -6.59.

upper-level inversions, and no inversions. It gives the total percentage frequencies of occurrence of different conditions (for all soundings in a given time period). In addition, for surface-based inversions, a cumulative frequency of inversions greater than 1,640; 820; and 320 feet is presented. For upper-level inversions, the table presents the percentage of the time when the base of the inversion occurs within specific atmospheric intervals (≤2,461 feet; 2,461 to 4,921 feet; >4,921 feet). In this analysis, only the lowest inversion in each sounding was considered.

Table R2-13 indicates that in the early morning hours, surface-based inversions occur about 85% of the time annually at each of the sites. The summer season has the highest percentage of morning inversions, but the winter season indicates the deepest inversions on the average. For example, 24.7% of the winter morning soundings had inversions greater than 1,640 feet deep; whereas only 6.2% of the summer inversions exceeded 1,640 feet.

Few of the morning soundings indicated upper-level inversions. A major reason for this result, as previously indicated, is the analysis scheme. In the afternoon, when surface-based inversions occur infrequently, a relatively high percentage of the soundings indicate upper-level inversions.

Table R2-13 also gives the frequency of three lapse rate conditions averaged for the entire atmospheric layer below the upper level inversions. The first (A) approximates a stable stratification of air; whereas the second (B) and third (C) approximate neutral and unstable stratifications, respectively. Category A also contains the standard atmospheric lapse rate of -3.6°F per 1,000 feet. As indicated, neutral conditions occur most frequently below elevated inversions during both the morning and afternoon periods. In summary, an analysis of five years (1960 to 1964) of radiosonde data at each of these locations suggests the following characteristics.

Morning Soundings:

- About 85% of all morning soundings (observation time at 5:00 A.M. MST) indicate surface-based inversions.
- Two-thirds of these have an increase of temperature with height of >6°F per 1,000 feet; this lapse rate approximates the minimum value for Turner's moderately stable class.
- About 50% of those inversions are 800 feet or more deep.
- Surface-based inversions occur most frequently during the summer (June to August), but the deepest inversions are most likely to occur in the winter (December to February).

Afternoon Soundings:

- Less than 10% of the afternoon soundings (observation time 5:00 P.M. MST) have surface-based inversions.
- More than 75% of the inversions that do occur are more than 300 feet deep but have an increase of temperature with height <6°F per 1,000 feet. Thus most of these inversions are characterized as slightly stable according to Turner's classification scheme.
- More than 50% of the afternoon soundings that have surface-based inversions are recorded during the winter.
- About 25% of all afternoon soundings indicate upper-level inversions (that is, an inversion with its base above ground level).
- About 80% of these inversions are more than 800 feet thick.
- The average lapse rate from the ground to the base of upper-level inversions is approximately adiabatic (-5.4°F per 1,000 feet).

These characteristics are generally applicable to the ES region. However, since both Lander and Grand Junction are more sheltered by large topographic barriers than most of the ES region, the frequency and depths of surface-based inversions could be overestimated.

Turner Stability Data. Since the majority of meteorological observation sites do not release radiosondes, and where they are used, a sounding analysis is only performed twice a day; an indirect method for determining hourly atmospheric stability is desirable. A widely accepted stability classification scheme was suggested by Turner (1964) to serve this function. This technique, which is derived chiefly from earlier experimental work by Pasquill (1961), defines stability near the ground in terms of net solar radiation and wind speed. The depth for which the technique is valid is on the order of 600 feet, but may be as low as 200 feet in nocturnal inversions. Table R2-14 presents a Turner-based atmospheric stability classification system. Included in the table are the approximate lapse rate intervals (AEC 1972) associated with each of the seven classes presented, as well as intervals for the three major classes of stability: unstable, neutral, and stable.

Table R2-15 presents the frequency of occurrence for the major stability classes at Fort Bridger and Rock Springs, Wyoming, as determined by the Turner system. The table presents annual and seasonal results determined from five years of hourly surface and cloud cover data. It should be noted that the direct application of the Turner system and the dispersion parameters associated with it might not be warranted in southern Wyoming (Crow and Hadley 1971).

TABLE R2-14

TURNER STABILITY CLASSIFICATION SYSTEM

Surface Wind (mph)	Day			Night	
	Incoming Solar Radiation			Thin Overcast†	
	Strong	Moderate	Slight	≤ 3/8 Cloud	≥ 4/8 Low Cloud
< 5	*A	A-B	B	G	F
5-7	A-B	B	C	F	E
7-11	B	B-C	C	E	D
11-13	C	C-D	D	D	D
> 13	C	D	D	D	D

Stability Class	Approximate Temperature Change with Height (°F per 1,000 feet)*	
*A - Extremely Unstable	< -10.4	< -8.2 (unstable)
B - Moderately Unstable	-10.4 to -9.3	
C - Slightly Unstable	-9.3 to -8.2	
D - Neutral	-8.2 to -2.7	neutral
E - Slightly Stable	-2.7 to +8.2	> -2.7 (stable)
F - Moderately Stable	+8.2 to 22.0	
G - Extremely Stable	> 22.0	

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†Neutral conditions assumed for all overcast conditions.

*Based on AEC (1972) temperature difference criteria.

TABLE R2-15

PERCENT FREQUENCY OF OCCURRENCE OF THREE STABILITY CLASSES AT FORT BRIDGER AND ROCK SPRINGS

(%)

Fort Bridger

Period	Stability Class		
	Unstable	Neutral	Stable
Annual	13	68	19
Winter	7	79	14
Spring	10	72	16
Summer	23	54	23
Fall	12	66	22

Rock Springs

Annual	17	54	29
Winter	7	67	26
Spring	14	63	23
Summer	29	39	32
Fall	16	47	37

Moisture

Relative Humidity. Relative humidity data for Wyoming are somewhat scarce; however, Table R2-16 lists values for the four first-order NWS stations in Wyoming (Lander, Sheridan, Casper, and Cheyenne). This table gives an indication of average relative humidity around the ES region.

The relative humidity is highest at night and lowest during daylight hours. This is a normal diurnal variation caused by the decreasing temperatures at nightfall. Warm air can hold more water vapor than cold air, such that the relative moisture content of the air increases when the temperature decreases. Table R2-17 gives the amount of seasonal diurnal variation for these stations. The average diurnal variation for January is one-third that of July (9 to 27). The average nighttime relative humidity is similar for the two months, but the average daytime relative humidity is much smaller in July than in January. The average diurnal variation for April is similar to that of October (24 to 21) and both the average nighttime and average daytime relative humidities are similar. In summary, April has the highest average nighttime relative humidity and July has the lowest average daytime relative humidity. The annual average relative humidity for Lander is 53%, Sheridan 62%, Casper 54%, and Cheyenne 56%. Since Lander and Casper are located closest to the ES region, their values should approximate or slightly exceed annual average values appropriate to the Bridger and Great Divide Basins. This trend is evidenced by an annual average relative humidity of 45% at Green River (Green River Community Profile 1976) and Rock Springs (Rock Springs Community Profile 1976), towns located near the central portion of the ES region.

Fog is not a prevalent condition in the ES region. The western portions, around Kemmerer and Sage, average only about five days per year, with fog creating visibility of less than 984 feet. East of the ES region, the number of fog days increases to eight or nine annually at stations like Dixon and Saratoga.

Total Precipitation. At similar elevations, precipitation is generally consistent throughout the ES region. The average annual melted precipitation is approximately 9.5 inches. However, there are significant topographic effects on precipitation, as can be seen in Map R2-7. The mountain ranges such as the Salt River, Wind River, and Wyoming, receive substantially more precipitation than the Bridger Basin. An example of this is the 18-inch average annual precipitation at Afton, located in the Star Valley, compared to 8 inches at Farson, situated in the center of the Bridger Basin.

A more pronounced illustration of the topographic influence on annual precipitation can be drawn from a data comparison between four reporting stations, two in and two adjacent to the Park Range. Two stations located near the peak elevations of this mountain range,

TABLE R2-16

RELATIVE HUMIDITY FOR WYOMING

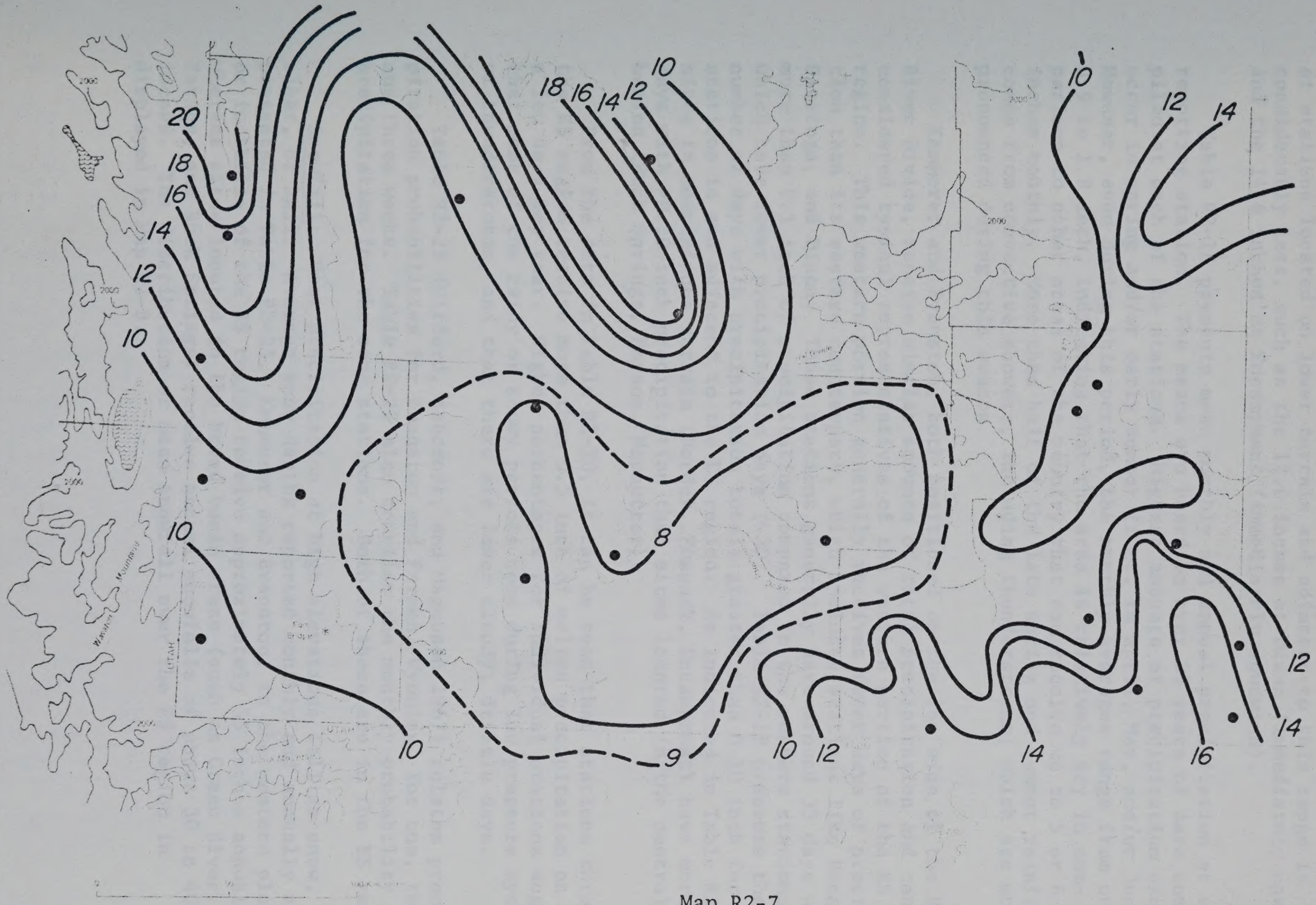
Station	Time (MST)	Relative Humidity (%)												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Lander (Hunt Field)	5:00 A.	65	67	68	68	70	64	56	54	58	64	69	67	64
	11:00 A.	57	55	51	45	45	41	34	33	36	44	55	58	46
	5:00 P.	56	51	50	41	41	35	28	25	32	43	58	60	43
	11:00 P.	64	65	63	59	60	55	44	44	48	57	67	65	58
Sheridan (County A.P.)	5:00 A.	73	74	77	77	79	81	72	70	73	73	75	73	75
	11:00 A.	62	61	59	48	48	49	36	35	40	44	57	61	50
	5:00 P.	66	64	61	46	48	48	35	32	39	47	65	68	52
	11:00 P.	71	73	74	70	71	74	62	58	64	66	73	71	69
Casper (Casper A.P.)	5:00 A.	67	68	72	73	76	68	65	62	62	64	68	67	68
	11:00 A.	56	55	52	45	45	38	30	29	33	41	52	56	44
	5:00 P.	60	57	48	43	44	35	26	23	31	41	58	61	44
	11:00 P.	66	67	69	67	70	62	52	49	51	59	66	66	62
Cheyenne (Municipal A.P.)	5:00 A.	59	61	67	74	78	75	73	72	69	67	62	59	68
	11:00 A.	48	48	48	47	47	42	36	36	37	39	45	47	43
	5:00 P.	55	54	51	48	49	44	40	40	39	45	54	56	48
	11:00 P.	61	62	68	68	75	69	66	65	63	64	60	59	65

Source: Climatological Summaries.

TABLE R2-17

DIURNAL VARIATION OF RELATIVE HUMIDITY

Station	Month	Average Nighttime Relative Humidity (%)	Average Daytime Relative Humidity (%)	Diurnal Variation
Lander (Hunt Field)	Jan	64	56	9
	Apr	64	43	23
	Jul	50	31	19
	Oct	60	44	16
Sheridan (County A.P.)	Jan	72	64	8
	Apr	74	47	27
	Jul	67	36	31
	Oct	70	46	24
Casper (Casper A.P.)	Jan	66	58	8
	Apr	70	44	26
	Jul	58	28	30
	Oct	62	41	21
Cheyenne (Municipal A.P.)	Jan	60	51	9
	Apr	71	48	23
	Jul	70	38	22
	Oct	66	42	24
Average	Jan	65	56	9
	Apr	70	46	24
	Jul	61	34	27
	Oct	64	43	21


20
18
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8
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12
14
16
14
12
Wasatch Mountains
UTAH
Fort Bridger

Map R2-7

Annual Average Precipitation in Inches
(See Map R2-1 for names of monitoring sites.)

Old Battle and North French Center, have an annual average precipitation of 40 and 41 inches, respectively. However, annual average precipitation at stations located on lower terrain and adjacent to this range is considerably less, such as the 12.6 inches at Dixon (immediately upwind) and the 14.6 inches at Encampment (immediately downwind).

Table R2-18 presents mean monthly and annual precipitation at each reporting station. The means are based on over 30 years of data compiled at each of the stations. Highest amounts of precipitation usually occur in spring and/or early summer (i.e., in April, May, and/or June). However, even during this period, the monthly averages range from only 0.9 to 1.8 inch, indicating that the area is relatively dry in comparison to other areas of the country that can receive up to 5 or 6 inches monthly. More than half of the late spring and summer rainfall comes from convective showers, including thunderstorms, which are most pronounced during this season.

Kemmerer and Evanston, both positioned on the lee side of the Bear River Divide, receive similar amounts of total precipitation and can be considered typical representatives of the western portion of the ES region. This western portion generally receives fewer days of precipitation than its eastern counterpart, which includes stations like Encampment, Saratoga, and Dixon. These stations generally have around 35 days with more than 0.1 inch of precipitation compared to the western stations, which have fewer precipitation days (∿30). Table R2-19 presents the number of days with precipitation totals greater than 0.10 inch for stations in and adjacent to the ES region. As indicated in Table R2-19, sites in mountainous terrain (Border, Foxpark, Encampment) have more days with >0.10 inch precipitation than sites located in the central basins (Rock Springs, Farson, Wamsutter).

From the data in Table R2-20, it can be seen that stations throughout the ES region receive more than 0.5 inch of melted precipitation on only a few days per year. Higher percentages for individual stations suggest that most of the rainy or snowy periods come during low pressure systems or thunderstorms, and that there are fewer cloudy, drizzle days.

Table R2-21 (Gifford, Ashcroft, and Magnuson 1967) relates precipitation probabilities for Evanston and Farson, Wyoming, for one, two, and three weeks. Table R2-22 also compiles the monthly probability of precipitation for the same stations. Both of these are in the ES region.

Snowfall. Most precipitation at high elevations fall as snow, sleet, or hail. Average snow depths reported monthly and annually are presented in Table R2-23. Kemmerer and Evanston, in the western plains or foothills of the ES region receive approximately 55 inches annually; whereas sites located in the broad basin areas (such as Green River, Farson, and Rock Springs) receive annual snowfalls of about 30 to 40 inches. The distribution of mean snowfall over the ES region is displayed in Map R2-8.

PRECIPITATION

Station	El. (feet)	Lat.	Long.	Years (at least)	Precip.	J	F	M	A	M	J	J	A	S	O	N	D	Annual
Evanston* E	6,860	41°16'	110°57'	30	Mean	0.72	0.86	0.91	1.05	1.19	1.04	0.65	0.92	0.68	0.93	0.84	0.71	10.50
Elk Mtn	7,270	41°41'	106°25'	30	Mean	0.72	0.86	1.33	1.58	1.39	0.98	0.84	0.93	0.94	0.82	0.77	0.63	11.79
Farson	6,591	42°07'	109°27'	30	Mean	0.41	0.46	0.45	0.69	0.96	0.85	0.64	0.61	0.67	0.69	0.36	0.32	7.11
Border 3N*	6,120	42°15'	111°02'	30	Mean	1.24	1.13	1.04	1.13	1.30	1.28	0.77	0.81	0.84	1.17	1.06	1.23	13.00
Kemmerer*	6,960	41°47'	110°32'	30	Mean	0.71	0.67	0.70	0.71	1.12	0.99	0.68	0.82	0.63	0.73	0.68	0.68	9.12
Green River*	6,089	41°32'	109°29'	30	Mean	0.49	0.52	0.67	0.99	1.20	0.92	0.57	0.84	0.65	0.98	0.50	0.38	8.71
Sage 4NNW*	6,321	41°52'	111°01'	30	Mean	0.67	0.66	0.70	0.79	1.20	0.96	0.65	0.85	0.70	0.84	0.66	0.57	9.25
Rock Springs City*	6,367	41°35'	109°13'	30	Mean	0.37	0.43	0.60	0.82	1.26	1.09	0.51	0.64	0.63	0.76	0.45	0.33	7.89
Rock Springs AP*	6,741	41°36'	109°04'	30	Mean	0.47	0.61	0.63	1.03	1.12	0.79	0.63	0.73	0.74	0.96	0.57	0.40	8.68
Wamsutter 1N	6,815	41°41'	107°59'	30	Mean	0.26	0.38	0.46	0.61	0.86	0.76	0.61	0.78	0.59	0.58	0.27	0.35	6.51
Dixon	6,364	41°02'	107°32'	30	Mean	0.93	0.69	1.17	1.27	1.26	0.95	1.22	1.14	0.85	1.28	0.79	1.00	12.55
Saratoga	6,786	41°27'	106°48'	30	Mean	0.46	0.40	0.72	0.94	1.25	1.04	0.85	0.97	0.75	0.91	0.52	0.48	9.29
Rawlins	6,736	41°48'	107°12'	30	Mean	0.62	0.71	0.93	1.07	1.43	0.90	0.87	0.76	0.96	0.98	0.53	0.67	10.43
Medicine Bow	6,560	41°54'	106°12'	30	Mean	0.58	0.60	0.80	0.98	1.60	1.30	0.98	0.79	0.86	0.82	0.58	0.55	10.44
Encampment 10ESE	7,387	41°11'	106°37'	30	Mean	0.84	0.81	1.50	1.73	1.79	1.31	1.20	1.33	1.06	1.21	0.90	0.88	14.56
Leo 6SW	6,000	42°11'	106°50'	30	Mean	0.61	0.62	0.98	1.29	1.37	1.05	0.91	0.91	0.80	0.95	0.73	0.54	10.76
South Pass City	7,875	42°28'	108°48'	30	Mean	0.89	0.91	1.10	1.49	1.32	1.35	0.78	0.70	0.83	0.98	0.85	0.76	12.16
Fox Park	9,060	41°05'	106°09'	30	Mean	1.38	1.37	1.70	1.68	1.56	1.58	1.68	1.49	1.16	0.97	1.10	1.03	16.70
Path Finder Dam	5,930	42°28'	106°51'	30	Mean	0.29	0.37	0.63	1.12	1.59	1.18	1.03	0.88	0.83	0.86	0.49	0.30	9.57
Laramie	7,189	41°19'	105°35'	30	Mean	0.39	0.42	0.77	1.25	1.54	1.46	1.73	1.20	0.82	0.67	0.47	0.44	11.16
Afton	6,210	42°44'	110°56'	30	Mean	1.53	1.51	1.55	1.52	1.95	1.96	1.06	1.05	1.15	1.53	1.52	1.59	17.92

*Indicates station in the ES region.

TABLE R2-19

MEAN NUMBER OF DAYS WITH PRECIPITATION >0.10 INCHES

Station	Period of Record (Years)	Mean Number of Days												Annual
		Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
Border 3N*	7	5	6	4	4	4	4	2	3	3	3	3	5	46
Dixon	7	3	2	4	2	3	2	4	3	3	3	3	2	34
Elk Mtn.	7	2	2	3	3	5	3	4	4	3	3	3	2	37
Encampment 1ESE	7	2	3	5	4	6	4	4	5	4	4	3	3	47
Evanston*	7	2	3	4	4	5	3	1	2	3	3	2	2	34
Farson	7	1	1	1	1	3	3	2	1	2	2	1	1	19
Fox Park	6	3	3	4	2	4	3	5	4	4	3	2	2	39
Green River*	7	2	2	2	2	3	2	1	2	3	1	2	2	24
Kemmerer*	7	3	3	3	1	4	2	2	3	2	2	2	2	29
Leo 6SW	6	2	2	4	3	4	3	2	2	2	2	2	1	29
Medicine Bow	7	2	2	3	2	5	3	4	3	2	2	2	1	31
Rawlins FAAAP	7	2	2	3	2	4	2	2	1	3	3	2	1	27
Rock Springs*	7	2	1	2	1	3	2	+	2	2	1	2	1	19
Rock Springs* FAA AP	7	2	2	1	2	3	2	1	1	2	2	2	2	22
Sage 4NNW*	6	3	3	3	3	5	2	2	3	2	1	2	2	31
Saratoga	6	1	1	4	1	4	2	1	4	2	3	1	1	25
Wamsutter 1N	7	1	1	1	1	3	3	2	2	2	2	1	1	20

Taken from - Climatic Summary of the United States Supplement, 1951-1960 (U.S. Department of Commerce).

*Indicates station in the ES region.

TABLE R2-20

MEAN NUMBER OF DAYS WITH PRECIPITATION ≥0.50 INCHES

Station	Period of Record (ft)	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Border 3N*	10	†	†	†	1	†	1	†	0	1	†	1	1
Dixon	10	†	†	†	†	1	†	1	†	1	1	†	1
Elk Mtn.	10	†	†	†	†	1	†	1	1	1	†	†	†
Encampment 1ESE	10	1	0	0	†	1	1	†	1	1	†	†	†
Evanston*	10	†	0	0	†	1	†	0	1	†	†	†	†
Farson	9	†	0	0	†	1	†	0	†	†	0	0	0
Fox Park	9	†	1	†	†	1	1	†	1	†	†	†	1
Green River*	10	†	†	†	†	1	1	†	†	†	†	†	†
Kemmerer*	10	†	0	†	†	1	†	0	†	†	†	†	†
Leo 6SW	9	0	†	†	†	1	1	1	†	†	†	†	†
Medicine Bow	10	0	0	†	†	1	†	†	†	†	†	†	†
Rawlins FAA AP	10	0	0	0	†	†	†	†	0	0	†	0	†
Rock Springs FAA AP*	10	0	0	†	†	1	†	†	†	0	†	†	0
Sage 4NN	10	1	†	†	†	†	†	†	0	†	†	†	†
Saratoga	10	0	0	†	†	†	†	†	†	†	1	†	†
Wamsutter 1N	10	0	0	0	†	†	0	†	1	†	†	0	†

†Not available

*Indicates station in the ES region.

TABLE DAQA-21

FARSON, WYOMING 483170
PRECIPITATION MEANS AND PROBABILITIES FOR 1-WEEK PERIODS

PERIOD BEGINS	MEAN PCPN	PROB O-T	PROBABILITY (PERCENT) OF RECEIVING AT LEAST THE FOLLOWING AMOUNTS (IN) OF PRECIPITATION 0.06	0.10	0.20	0.40	0.60	0.80	1.00	1.40	2.00
MAR 01	.12	34	48	38	20	6	2				
MAR 08	.11	33	49	38	18	4	1				
MAR 15	.09	38	48	38	19	5	1				
MAR 22	.14	42	47	39	24	8	3	1			
MAR 29	.14	41	49	43	29	13	6	3	1		
APR 05	.23	40	50	44	31	15	7	3	1		
APR 12	.09	38	51	43	29	13	6	3	2		
APR 19	.26	31	57	50	35	18	9	5	2		
APR 26	.22	28	60	53	38	20	10	5	3		
MAY 03	.20	37	53	47	35	20	11	7	4	2	
MAY 10	.29	41	50	45	35	21	13	8	6	2	1
MAY 17	.19	37	54	48	37	21	12	7	4	2	
MAY 24	.27	31	59	52	39	22	12	6	3	1	
MAY 31	.21	29	57	51	37	20	10	6	3	1	
JUN 07	.19	35	52	45	32	16	8	4	2		
JUN 14	.15	42	47	41	30	16	8	5	2	1	
JUN 21	.24	45	45	39	28	15	8	5	3	1	
JUN 28	.09	47	42	36	24	11	6	3	2		
JUL 05	.16	45	41	35	23	11	5	3	1		
JUL 12	.15	44	41	34	23	11	6	3	2		
JUL 19	.10	41	44	37	23	10	4	2	1		
JUL 26	.18	39	48	41	27	11	5	2	1		
AUG 02	.13	48	43	37	25	10	4	1			
AUG 09	.08	50	40	33	20	7	2	1			
AUG 16	.15	40	47	39	24	8	3	1			
AUG 23	.14	41	48	41	26	11	5	2	1		
AUG 30	.17	48	42	37	26	13	6	3	2		
SEP 06	.14	50	40	34	23	11	5	3	1		
SEP 13	.11	51	39	33	23	11	6	3	1		
SEP 20	.20	53	39	34	25	13	7	4	2		
SEP 27	.10	54	40	36	26	13	7	4	2	1	
OCT 04	.22	51	41	37	27	15	8	5	3	1	
OCT 11	.13	50	41	37	28	17	10	6	4	1	
OCT 18	.26	50	42	38	29	17	11	7	4	2	
OCT 25	.13	49	42	37	25	12	6	4	2	1	
NOV 01	.09	53	38	32	20	8	3	1			
NOV 08	.12	54	39	34	23	10	4	2	1		
NOV 15	.16	55	39	34	23	10	4	2	1		
NOV 22	.04	60	32	26	15	4	1				
NOV 29	.07	57	32	24	11	2					
DEC 06	.06	52	36	26	10	1					
DEC 13	.05	49	39	28	11	1					
DEC 20	.09	42	45	34	15	2					
DEC 27	.10	40	48	38	17	3					
JAN 03	.09	46	43	34	17	4	1				
JAN 10	.09	48	39	31	17	5	1				
JAN 17	.10	43	45	36	20	5	1				
JAN 24	.13	38	50	41	24	7	2				
JAN 31	.13	37	52	43	26	8	3	1			
FEB 07	.14	39	51	42	23	6	2				
FEB 14	.08	41	48	38	18	4	1				
FEB 21	.11	39	47	37	19	5	1				

FARSON, WYOMING 483170
PRECIPITATION MEANS AND PROBABILITIES FOR 2-WEEK PERIODS

PERIOD BEGINS	MEAN PCPN	PROB O-T	PROBABILITY (PERCENT) OF RECEIVING AT LEAST THE FOLLOWING AMOUNTS (IN) OF PRECIPITATION 0.06	0.10	0.20	0.40	0.60	1.00	1.40	2.00	4.00
MAR 01	.23	15	72	62	42	17	7	1			
MAR 15	.23	19	71	62	44	20	9	2			
MAR 29	.37	18	73	67	53	32	19	6	2		
APR 12	.35	12	77	71	56	35	21	8	3		
APR 26	.42	9	81	74	61	40	27	12	5	2	
MAY 10	.49	23	70	65	56	40	29	15	8	3	
MAY 24	.48	12	82	77	65	44	28	11	4	1	
JUN 07	.34	24	68	63	52	34	22	9	4	1	
JUN 21	.33	27	65	60	47	30	18	7	3	1	
JUL 05	.31	28	58	52	40	24	15	6	3	1	
JUL 19	.28	18	72	65	49	26	13	3	1		
AUG 02	.21	25	66	59	43	21	10	2			
AUG 16	.28	18	70	62	46	25	13	4	1		
AUG 30	.30	25	66	60	47	27	15	5	1		
SEP 13	.30	32	60	55	43	26	16	6	2		
SEP 27	.32	32	60	55	44	29	19	8	4	1	
OCT 11	.39	31	63	59	49	34	24	11	5	1	
OCT 25	.22	28	63	58	44	23	12	4	1		
NOV 08	.28	35	61	57	44	24	12	3	1		
NOV 22	.11	39	52	45	28	9	3				
DEC 06	.13	26	62	51	27	6	1				
DEC 20	.20	15	72	60	36	11	3				
JAN 03	.18	25	60	51	34	14	6	1			
JAN 17	.23	12	78	69	46	18	6				
JAN 31	.27	16	76	68	49	22	9	2			
FEB 14	.19	15	75	66	42	14	4				

FARSON, WYOMING 483170
PRECIPITATION MEANS AND PROBABILITIES FOR 3-WEEK PERIODS

PERIOD BEGINS	MEAN PCPN	PROB O-T	PROBABILITY (PERCENT) OF RECEIVING AT LEAST THE FOLLOWING AMOUNTS (IN) OF PRECIPITATION 0.06	0.10	0.20	0.40	0.60	1.00	1.40	2.00	4.00
MAR 01	.31	11	83	76	59	31	15	3			
MAR 22	.51	5	87	81	67	43	28	11	4	1	
APR 12	.56	4	90	85	74	53	38	18	9	3	
MAY 03	.69	11	83	79	70	55	43	25	15	7	
MAY 24	.67	4	91	88	78	58	42	21	10	3	
JUN 14	.48	13	81	76	65	46	32	15	7	2	
JUL 05	.41	18	72	66	54	37	25	11	5	1	
JUL 26	.39	8	85	79	63	38	21	6	2		
AUG 16	.45	12	80	75	62	40	26	10	4	1	
SEP 06	.44	19	76	71	60	40	26	10	4	1	
SEP 27	.45	23	70	66	57	42	31	17	9	3	
OCT 18	.48	13	80	75	62	42	27	12	5	2	
NOV 08	.33	28	70	66	56	34	18	5	1		
NOV 29	.20	17	76	67	42	12	3				
DEC 20	.28	5	82	73	51	24	11	2			
JAN 10	.32	4	89	82	62	30	13	2			
JAN 31	.35	5	89	82	64	35	17	4	1		

TABLE R2-22

MONTHLY PROBABILITY OF PRECIPITATION

					Percent Probability of Receiving at Least the Following Amounts of Precipitation (%)								
					Inches								
Station	El.(ft)	Lat.	Long.	Month	0.06	0.10	0.20	0.40	0.60	0.80	1.00	1.40	2.00
Evanston	6,860	41°16'	110°57'	March	68	62	40	17	8	3	1		
				April	68	60	44	20	9	4	2		
				May	62	57	48	27	15	11	6	2	1
				June	49	48	47	16	8	4	2	1	
				July	44	38	32	17	8	5	3		
				Aug.	52	48	35	17	8	4	2	1	
				Sept.	44	38	31	16	9	5	2		
				Oct.	56	52	38	19	9	5	2		
				Nov.	52	50	36	19	9	4			
				Dec.	60	48	29	11	3	1			
				Jan.	65	53	37	18	8	4	2		
				Feb.	69	60	42	20	8	4	2		

					Inches							
					0.06	0.10	0.20	0.40	0.60	1.00	1.40	2.00
Farson	6,591	42°07'	109°26'	March	84	80	60	40	21	8	2	1
				April	90	84	74	50	36	16	5	2
				May	88	81	72	54	40	22	11	4
				June	82	82	72	49	37	17	8	2
				July	82	77	62	45	30	14	6	2
				Aug.	81	76	63	39	25	8	3	1
				Sept.	74	68	59	41	28	16	8	2
				Oct.	80	74	61	42	29	14	7	2
				Nov.	74	67	48	24	10			
				Dec.	80	70	48	20	8	2		
				Jan.	89	82	62	28	12	2		
				Feb.	89	82	64	34	15	4	1	

Table computed from Climatic Summary of the United States, Supplement for 1931-1952 (U. S. Department of Commerce)

TABLE R2-23

TOTAL SNOWFALL AT STATIONS IN SOUTHERN WYOMING

(inches)

Station	Lat.	Long.	Period of Record (Years)	Elevation (feet)	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Border 3N*	42°15'	111°02'	D20	6,120	16.0	14.6	10.9	6.9	1.1	T	T	0	0.6	2.6	6.9	9.3	68.8
			G18		15.3	13.9	11.6	6.6	1.5	0.2	T	T	0.3	3.2	8.7	13.8	75.1
Dixon	41°02'	107°32'	D9	6,359	14.4	13.0	10.9	4.5	1.9	T	0	0	1.0	4.2	8.7	16.8	75.4
			G20		15.7	11.3	15.1	9.4	1.2	T	0	0	0.3	4.4	9.1	16.5	83.0
Elk Mountain	41°41'	106°25'	D24	7,103	19.9	26.7	21.7	21.5	10.4	0.1	0	0	2.7	11.3	9.8	17.7	141.8
			G17		10.6	9.6	19.2	16.8	3.7	0.7	T	T	1.1	4.6	8.8	9.4	82.5
Encampment 10ESE	41°11'	106°37'	D19	7,387	9.7	10.7	9.1	4.4	3.1	0.1	0	0	0.6	4.8	9.0	8.7	60.2
			G22		12.2	10.7	16.1	10.8	3.0	0.1	T	0	0.9	4.1	8.8	11.1	77.8
Evanston 1E*	41°16'	110°57'	D32	6,860	9.6	10.2	10.6	6.0	3.3	0.2	T	0	1.1	4.3	5.9	7.2	58.4
			G19		9.8	12.8	12.5	8.0	1.9	0.4	0	0	0.9	3.7	8.9	9.4	68.3
Farson	40°07'	109°25'	D19	6,600	3.3	4.6	2.9	2.4	0.5	T	0	T	0.3	1.1	2.2	3.1	20.4
			G16		5.5	5.7	6.3	5.3	1.8	0.2	T	0	0.1	2.8	5.2	4.4	37.3
Green River*	41°32'	109°29'	D23	6,109	4.9	5.4	4.8	3.2	1.2	T	0	0	0.2	2.4	3.8	3.5	29.4
			G18		6.2	7.3	7.5	7.3	2.2	0.2	0	0	0.1	3.7	4.1	5.0	43.6
Kemmerer*	41°48'	110°32'	G15	6,954	9.3	8.6	10.1	7.2	2.1	0.6	0	0	0.4	2.7	6.7	7.7	55.4
Leo 6SW	42°12'	106°50'	D11	6,000	9.9	8.4	9.2	4.4	3.3	0	0	0	0.8	3.7	3.5	8.6	51.8
			G19		11.3	8.5	10.9	9.2	2.9	0.8	0	T	0.8	3.3	7.9	7.5	63.1
Rawlins	41°47'	107°14'	D28	6,764	7.2	8.6	9.1	6.1	2.9	0.1	0	0	0.5	4.1	5.2	9.0	52.8
			G8		10.9	9.1	9.1	2.8	2.7	T	T	T	0.8	2.7	6.5	9.0	53.6
Sage*	41°49'	110°58'	D8	6,331	7.3	6.9	6.5	4.9	0.8	0	0	0	0.4	2.1	6.7	5.9	41.5
			G16		6.7	6.8	6.9	5.1	1.9	0.1	T	0	0.4	2.9	5.4	7.0	43.2
Saratoga	41°30'	160°47'	D26	6,794	10.1	8.6	9.6	5.3	4.3	0.1	0	0	0.3	3.3	5.0	8.3	54.9
			G21		7.0	6.0	8.1	7.1	2.5	0.3	0	0	0.8	0.3	5.8	7.3	48.0
Wamsutter 1N	41°41'	107°59'	G8	6,815	4.4	6.6	6.1	5.2	0.9	0.1	T	0	T	2.2	3.3	4.5	33.3
Rock Springs FAA AP*	41°36'	109°04'	37	6,741	5.9	6.4	6.2	4.0	1.0	0.1	T	T	0.2	3.1	5.7	4.8	37.6
Afton	42°44'	110°56'	38	6,210	18.0	17.0	14.1	8.4	2.0	0.2	0	0	0.7	3.3	9.5	13.5	87.5
Casper	42°51'	106°20'	D*20	5,124	7.3	9.7	11.7	10.0	2.8	0.1	0	0	0.2	6.5	8.1	10.1	66.5
			G*15		9.8	9.6	12.8	13.7	2.6	0.2	0	0	0.9	3.6	8.6	7.3	69.1

TABLE R2-23 (Continued)

TOTAL SNOWFALL AT STATIONS IN SOUTHERN WYOMING

(inches)

Station	Lat.	Long.	Period of Record (Years)	Elevation (feet)	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Fox Park	41°05'	106°09'	46	9,060	22.6	22.3	25.9	23.3	10.3	1.1	T	0.1	2.9	9.5	17.7	18.8	154.5
Laramie	41°18'	105°34'	18	7,211	5.4	5.4	7.0	5.4	3.7	0.7	T	T	0.7	2.4	5.8	5.3	418
Pathfinder Dam	42°28'	106°50'	D*25	5,915	4.5	5.7	6.0	7.7	2.8	T	0	0	0.6	3.7	4.9	6.5	42.4
			G*18.		3.6	4.4	5.7	7.6	1.6	0.3	0	0	0.4	1.3	5.9	3.6	34.4
South Pass City	42°28'	104°48'	10	7,805	17.4	14.3	17.6	23.0	8.2	0.4	T	0	1.0	5.1	19.1	15.3	121.4

Reference: Climatic Summary of the U.S., Supplement for 1931-1952 (U.S. Department of Commerce)

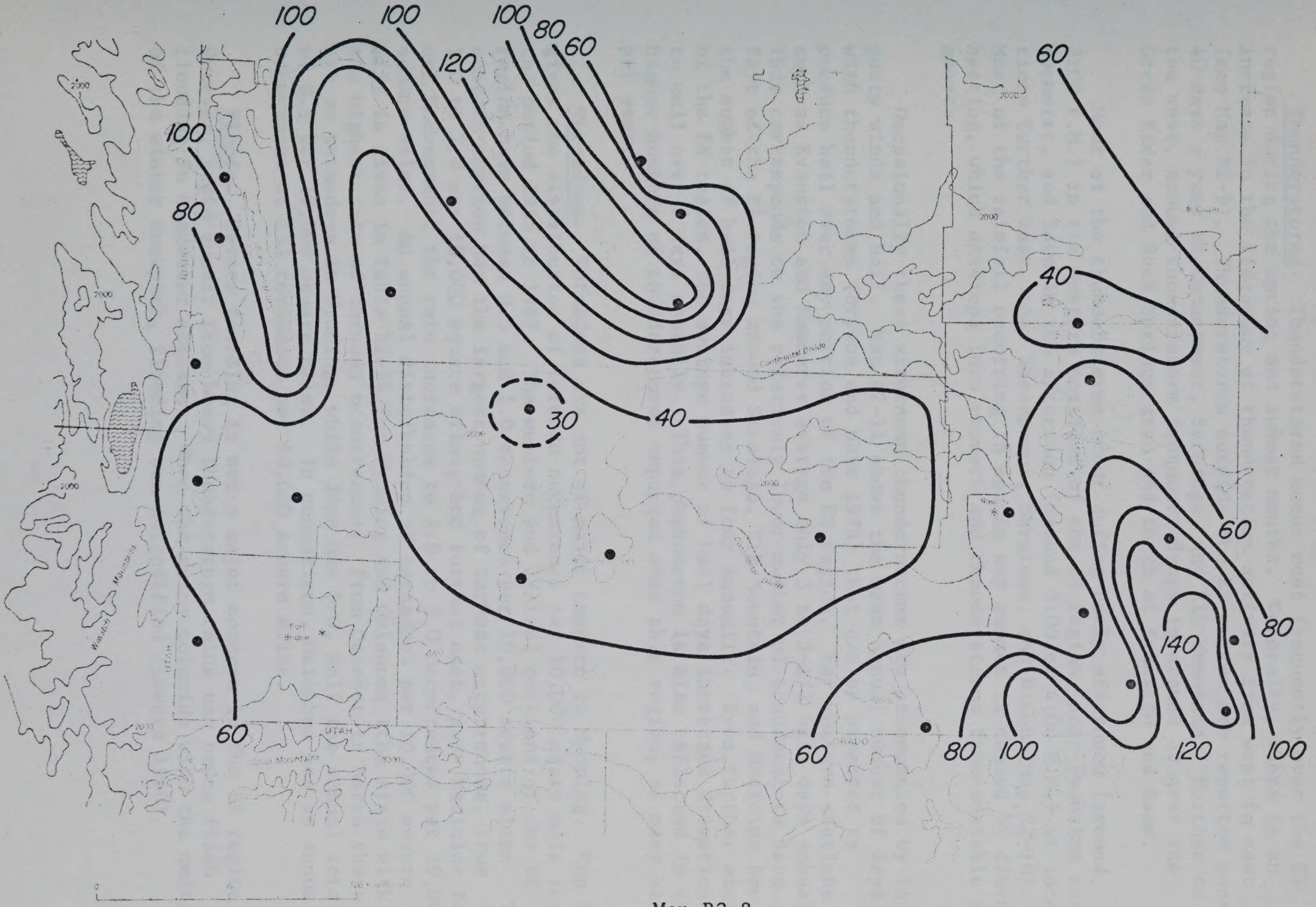
† From Wyoming Weather Facts (Wyoming Natural Resources Board 1966).

D = Means or extremes for the period of record prior to 1931

G = Means or extremes for the period of record beginning with 1931

*Indicates station in the ES region

T = Trace


100
100
100
80
60
60
120
100
80
30
40
40
60
80
140
60
80
100
120
100
60
Continental Divide
Fort Bridger
Rawlins
UTAH
Wasatch Mountains
Uinta Mountains
2000

Map R2-8

Average Annual Snowfall in Inches
(See Map R2-1 for names of monitoring sites.)

Severe Weather Events

Thunderstorms. Thunderstorms occur most frequently over the ES region during the spring and summer months. Generally, there is an increase in the frequency of thunderstorm activity from west to east (see Map R2-9). Thunderstorms outside the ES region are reported nearly 40 days a year at Encampment, Saratoga, and Elk Mountain. Further to the west, annual thunderstorm frequency drops to around 30 near the Green River and Rock Springs area and to 25 at Evanston and Sage.

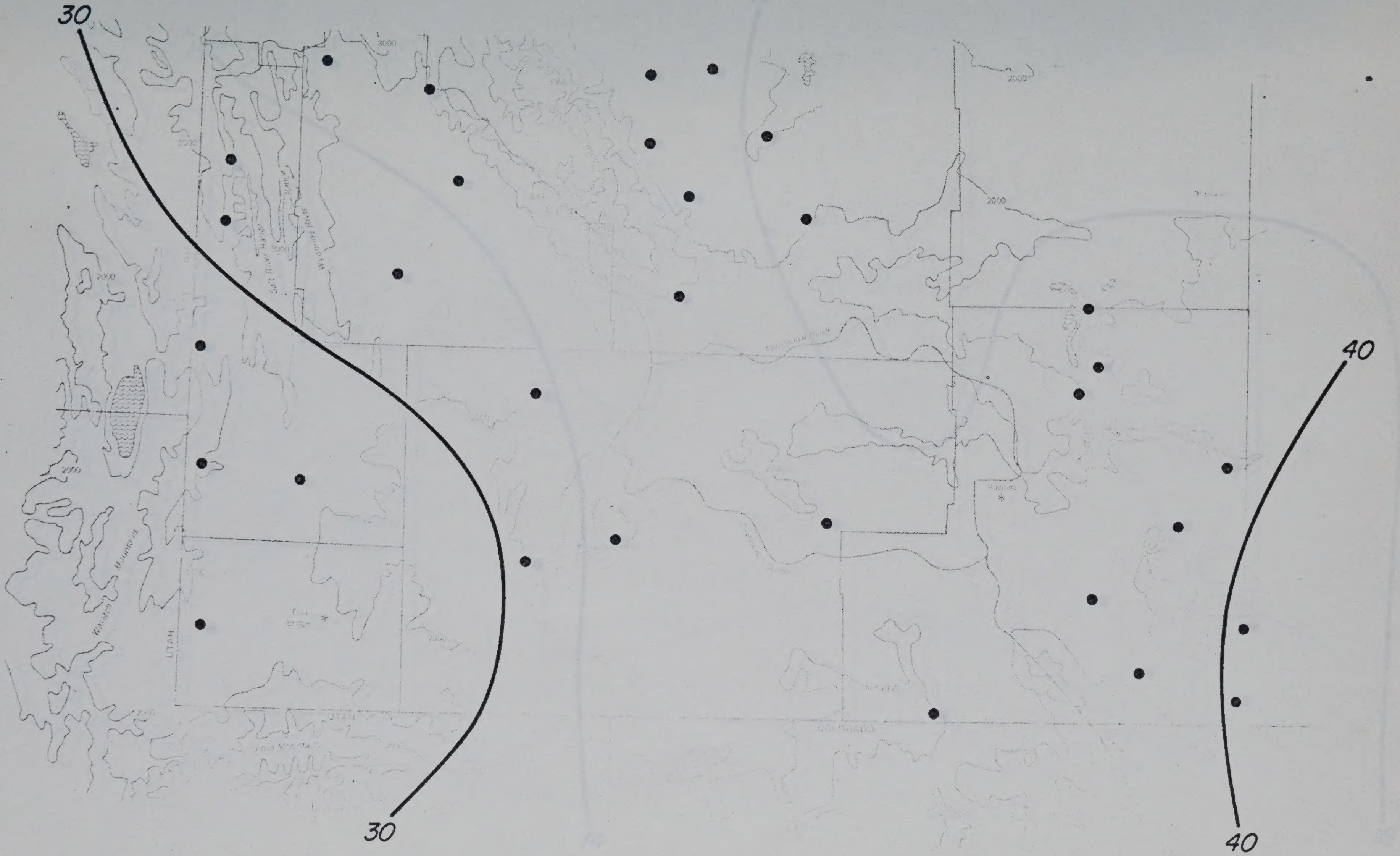
Most of the thunderstorms occur during early afternoon (around 2:00 P.M.) in the western portions of the ES region, near Evanston and Kemmerer, and late in the afternoon (around 3:00 or 4:00 P.M.) at locations further east, near Encampment, Saratoga, and Dixon (Map R2-10). Most of the rainfall occurring in spring and summer is caused by diurnal heating, which develops into showers and thunderstorms from unstable air masses.

Occasionally these afternoon thunderstorms are accompanied by local gusty winds and hail. Map R2-11 shows the mean annual number of days with thunderstorms (Bryson and Hare 1974) that can be expected to produce hail over any portion of the ES region. Far western stations such as Evanston and Kemmerer average only 3 to 3-1/2 hail days annually. This corresponds to the relatively lower number of thunderstorm days. East of the ES region around Saratoga, Elk Mountain, and Medicine Bow the number of hail days increases to four annually. Even further east of the ES region, the average number of hail days increases dramatically to well over 7 days annually. This phenomenon is also reflected in the higher numbers of thunderstorms reported over this region, as many as 45 per year.

Tornadoes. Tornadoes are not of major concern in Wyoming. Map R2-12 gives the distribution of tornado occurrence per 10,000 sqare mile for the period 1955 to 1967. The western and central portions of the ES region have between 0.5 and 1.0 occurrence per 10,000 square miles. The eastern portion has the largest number of tornado occurrences, from 1.0 to 2.0 per 10,000 square miles, and further east, past Medicine Bow and Encampment, the rate increases to 2.0 to 3.0 occurrences per 10,000 square miles. An annual distribution of tornadoes per 10,000 square mile is given in Table R2-24 for Wyoming and Oklahoma (the state with the highest rate of tornado occurrence). From October to March there are no tornadoes in Wyoming, while June has 5.0, half the annual total of 9.9 per 10,000 square miles. In comparison, Oklahoma has an annual occurrence of 133 tornadoes per 10,000 square miles.

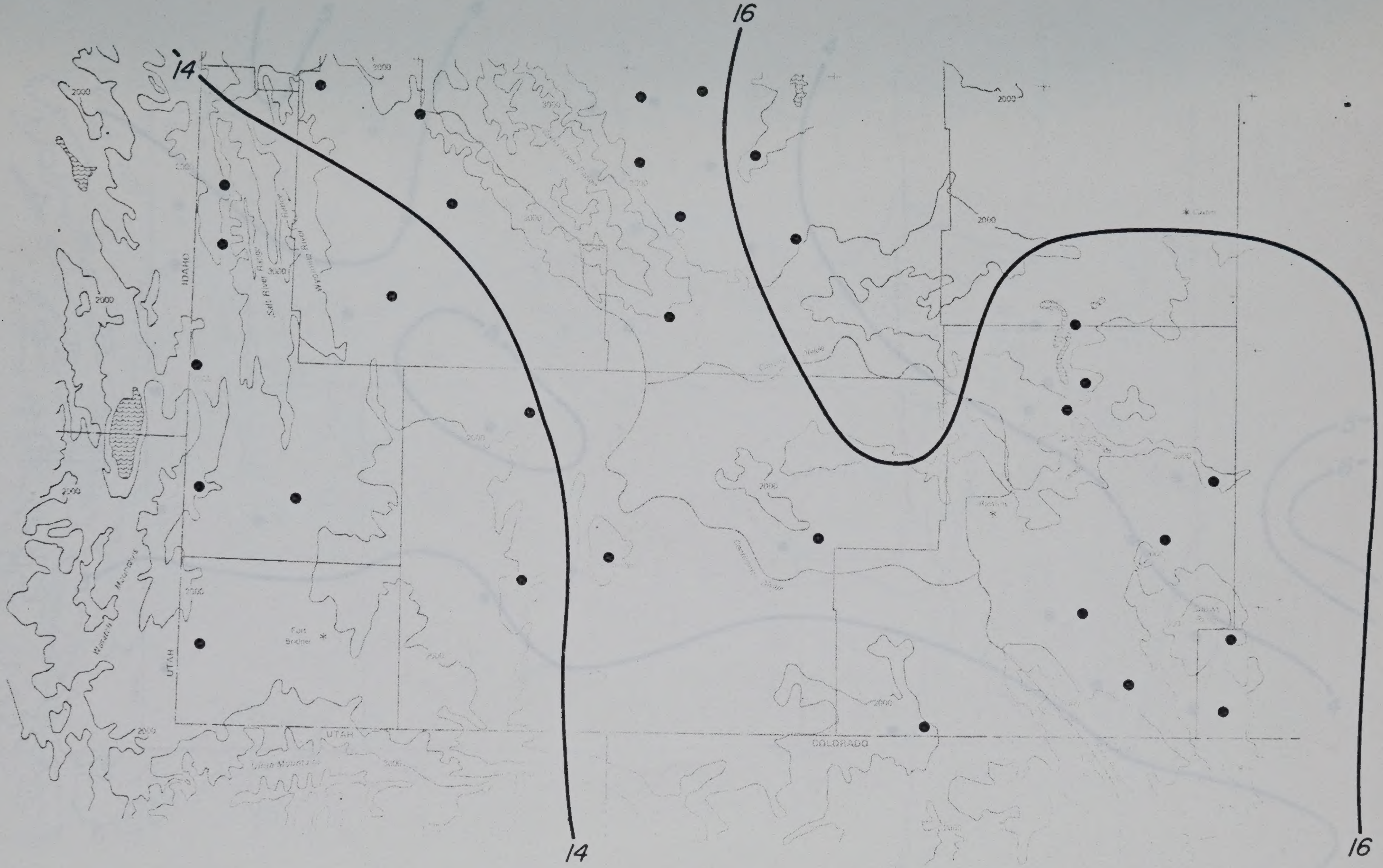
Floods. Severe flooding is not a major concern in the ES region. However, rapid runoff from heavy thunderstorm rains can cause flash flooding in headwater streams. When the rains coincide with the melting of the winter snowpack, flooding can intensified (Lowers 1960).

701213


30
30
40
40
UTAH

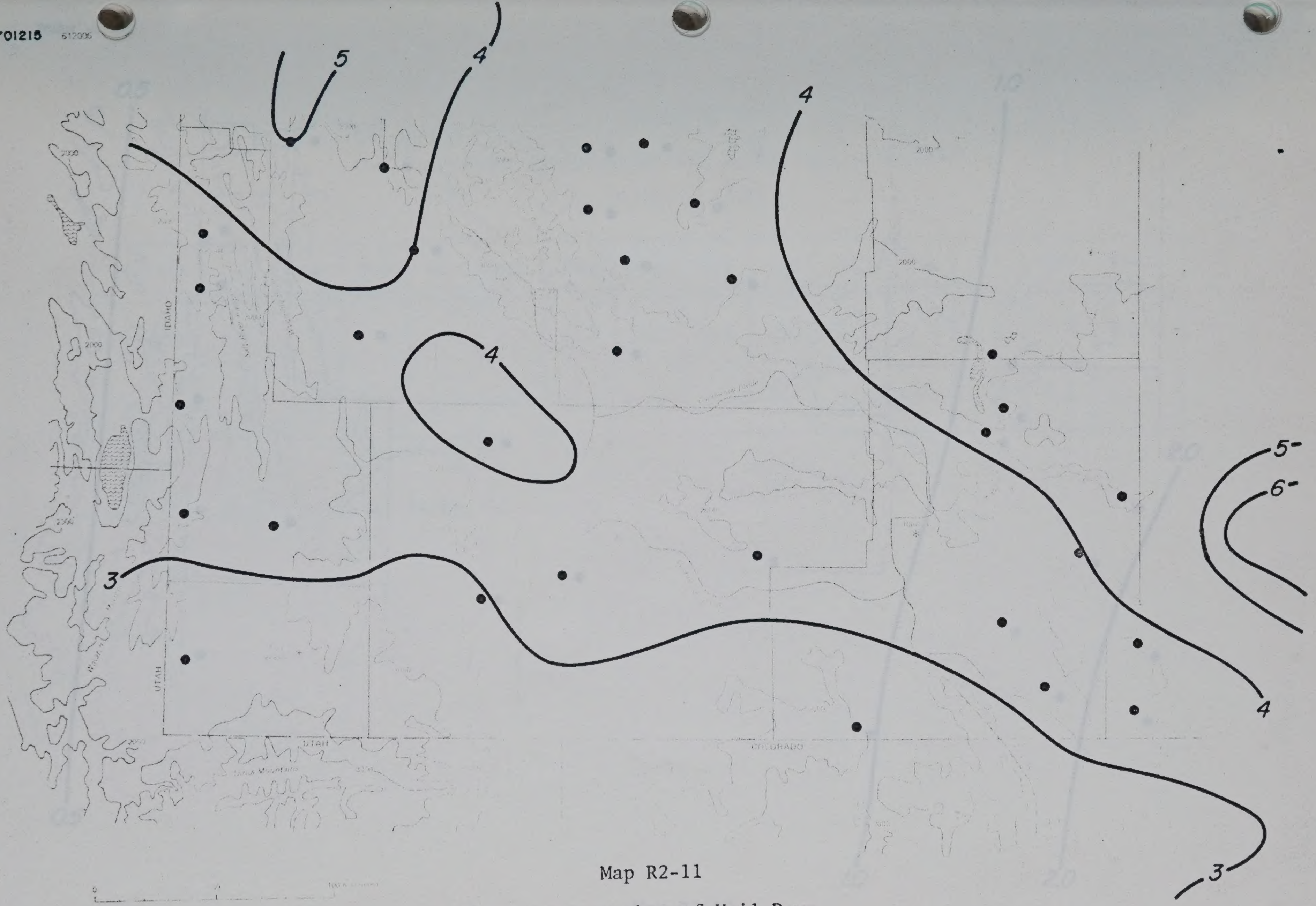
Map R2-9

Mean Annual Number of Days with Thunderstorms (1953 to 1962)
(See Map R2-1 for names of monitoring sites.)


14
16
14
16
IDAHO
UTAH
UTAH
COLORADO
Salt River Range
Wyoming Range
Fort Bridger
Uinta Mountains
2000

Map R2-10

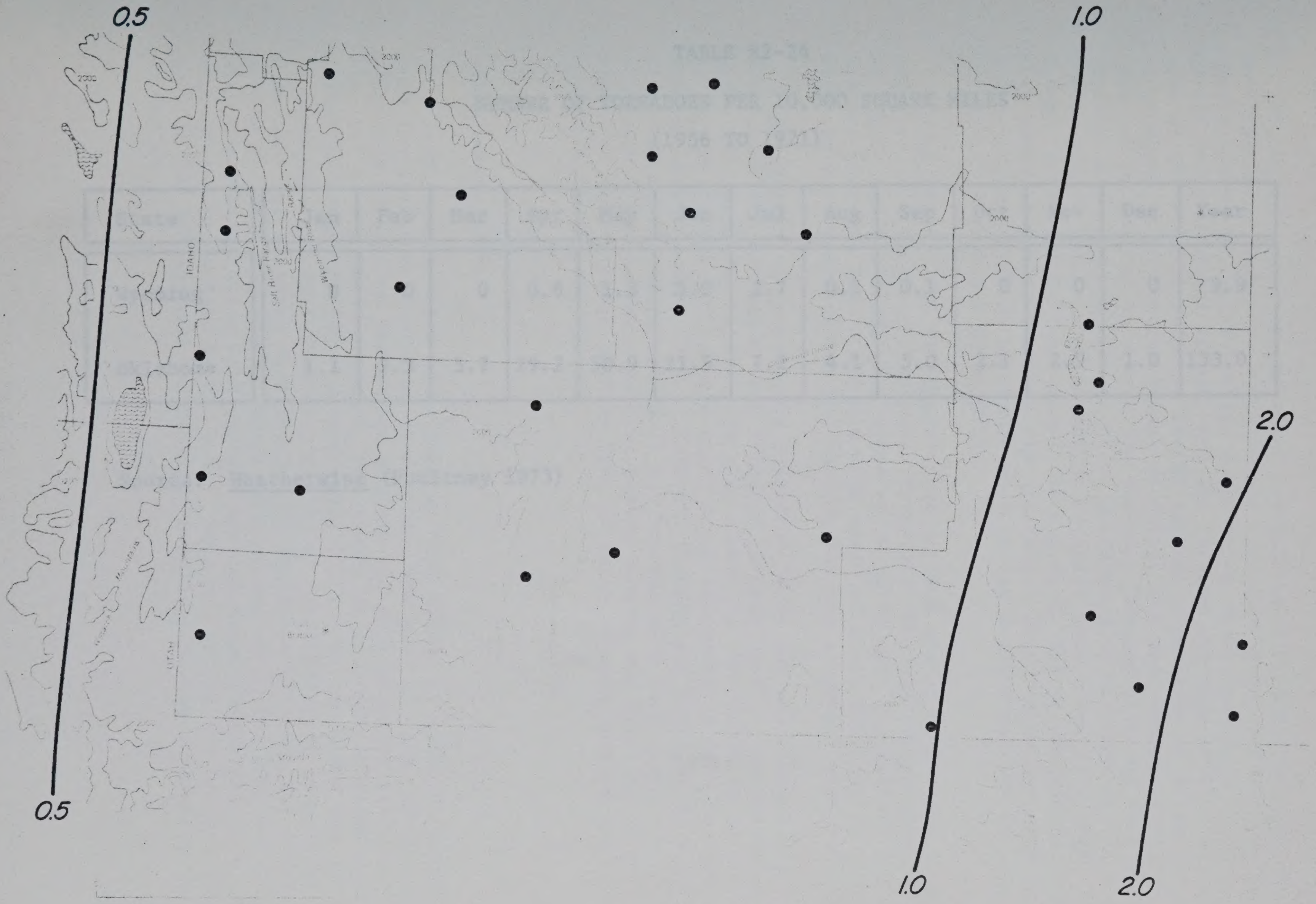
Hour (Local Standard Time) of Maximum Frequency of Thunderstorms (June to August)
(See Map R2-1 for names of monitoring sites.)


5
4
4
4
3
4
3
5
6
IDAHO
UTAH
UTAH
COLORADO
Uinta Mountains
2000

Map R2-11

Mean Annual Number of Hail Days
(See Map R2-1 for names of monitoring sites.)

701211


0.5
1.0
2.0
IDAHO
UTAH
0.5
1.0
2.0

Map R2-12

Distribution of Tornado Occurrence per 10,000 Square Miles from 1955 to 1967
(See Map R2-1 for names of monitoring sites.)

Source: Bryson and Hare 1974

TABLE R2-24

NUMBER OF TORNADOES PER 10,000 SQUARE MILES

(1956 TO 1971)

State	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Wyoming	0	0	0	0.6	1.3	5.0	2.7	0.2	0.1	0	0	0	9.9
Oklahoma	1.1	2.3	5.7	29.2	50.9	21.5	7.2	4.1	5.0	2.1	2.9	1.0	133.0

Source: Weatherwise (Poultney 1973)

Droughts. A dry spell is defined as a two-week period during which no measurable precipitation (<0.01 inch) occurs. Since most of the ES region is semiarid, dry spells are not unusual.

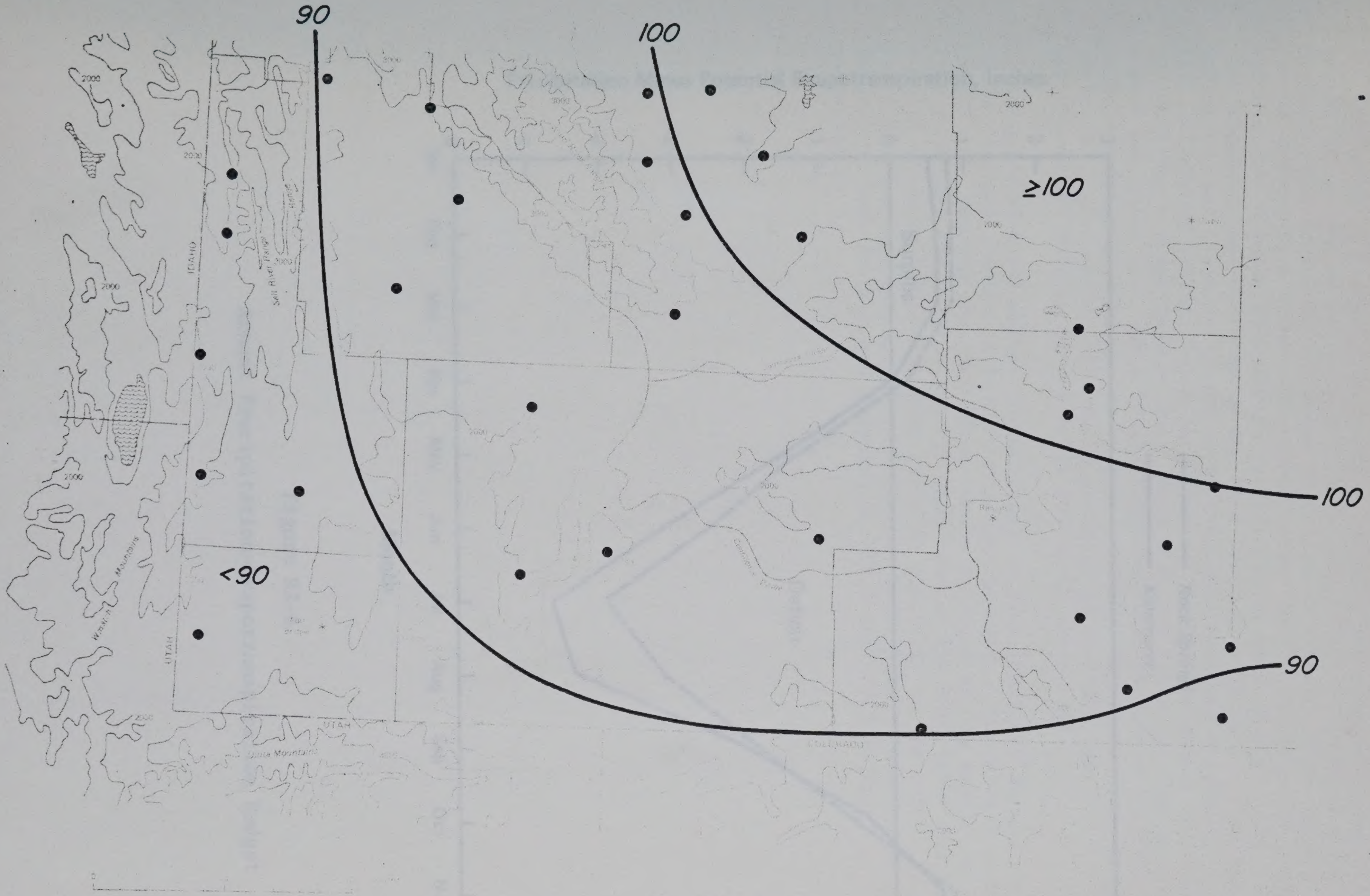
Droughts usually occur after several weeks of less-than-average precipitation. However, droughts can conceivably develop with normal precipitation but above-average evaporation rates, as might occur with persistent incursions of dry warm air (Bryson and Hare 1974). Since most of the precipitation in the ES region, especially in large basins, is produced by convective shower activity, the mean monthly precipitation can be reached in one or two storms. Consideration of this factor together with the high potential of subsidence of warm dry air in areas positioned in the lees of mountains suggests that there is a high drought potential in the region. As expected, 25% of the months each year experience severe or extreme droughts. This figure compares to values of less than 5% in places such as New England and the Pacific Northwest (Bryson and Hare 1974).

High Winds. Map R2-13 gives the maximum annual wind speed to be expected at a 100-year recurrence interval. The western portion of the ES region has a maximum wind speed of 80 to 90 mph; the central and eastern portions have a maximum wind speed of 90 to 100 mph; and the area north of Medicine Bow and Seminoe Dam has a maximum wind ≥100 mph.

Blizzards. As previously indicated, snow can fall frequently throughout the ES region from November through April. The accumulation potential generally varies with site elevation. Snowfalls of 10 to 15 inches or more for any one storm occur infrequently outside mountainous areas (Lowers 1960). However, blowing and drifting snow associated with strong winter winds is not unusual even with light accumulations. Ground blizzards (the severe blowing and drifting of ground snowcover during clear periods that severely reduces surface visibility) can also occasionally occur.

Evapotranspiration

Evapotranspiration is defined as that amount of moisture evaporated from the soil and transpired by plants. The rate of evapotranspiration primarily depends on the amount of heat and soil moisture available. If the soil were always saturated, the amount of moisture released would equal the potential evapotranspiration (PET). By comparing the amount of available precipitation with the water need (PET), it is possible to determine the seasonal distribution of available moisture for plant growth (Critchfield 1966). During the winter or during very wet periods when the precipitation rate exceeds that of evapotranspiration, a water surplus can accumulate in the soil. However, during dry spells, the rate of PET far exceeds the moisture supply, creating a moisture deficit in the soil.


90
100
≥100
100
<90
90
IDAHO
UTAH
Salt River Range
Wasatch Mountains
Uinta Mountains
UTAH
COLORADO

Map R2-13

Annual Extreme Wind Speed (mph), 100-Year Mean Recurrence Interval at 30 Feet Above Ground
(See Map R2-1 for names of monitoring sites.)

Source: Bryson and Hare 1974

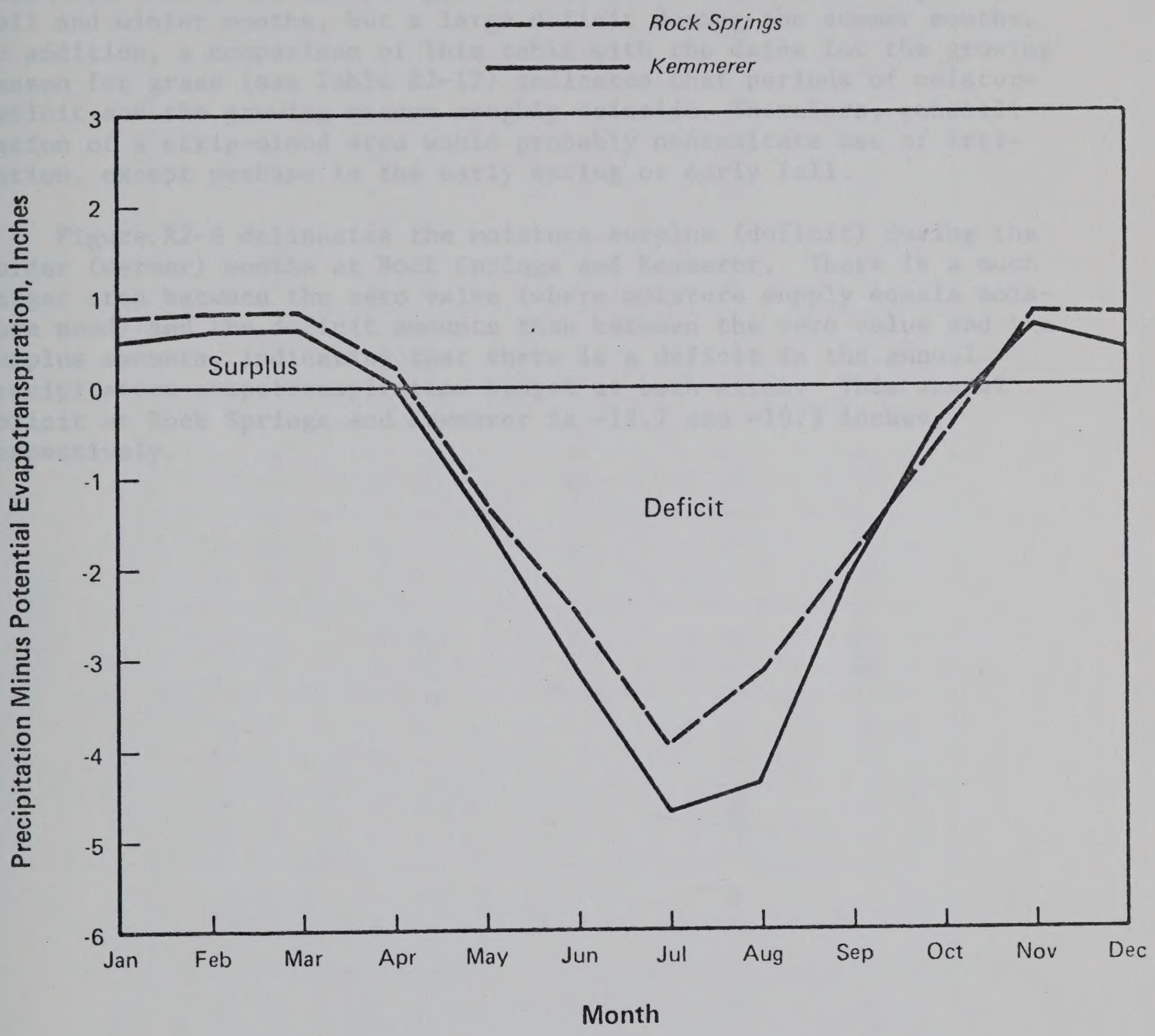


Figure R2-8

Annual Precipitation-Evapotranspiration Budget

701027

Table R2-25 presents the monthly, annual, and seasonal normals of precipitation and evapotranspiration for sites located in southwestern Wyoming. The annual period shown in the table includes those months having mean monthly temperatures that exceed 32°F. The seasonal periods reflect the 32°F and 28°F frost-free periods at each of the sites. Note that some of these stations do not have frost-free periods. This table indicates that there is a surplus of available moisture during the late fall and winter months, but a large deficit during the summer months. In addition, a comparison of this table with the dates for the growing season for grass (see Table R2-12) indicates that periods of moisture deficit and the growing season roughly coincide. Therefore, rehabilitation of a strip-mined area would probably necessitate use of irrigation, except perhaps in the early spring or early fall.

Figure R2-8 delineates the moisture surplus (deficit) during the colder (warmer) months at Rock Springs and Kemmerer. There is a much larger area between the zero value (where moisture supply equals moisture need) and the deficit amounts than between the zero value and the surplus amounts, indicating that there is a deficit in the annual precipitation-evapotranspiration budget at both sites. This annual deficit at Rock Springs and Kemmerer is -12.7 and -10.3 inches, respectively.

TABLE R2-25

NORMALS OF PRECIPITATION AND EVAPOTRANSPIRATION

(INCHES)

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual	Season	
														32°	28°
Evanston 1E															
P	0.7	0.9	0.9	1.1	1.2	1.0	0.7	0.9	0.7	0.9	0.8	0.7	10.5	*	2.5
PET	0.0	0.0	0.0	1.0	2.4	3.4	4.6	4.0	2.6	1.3	0.0	0.0	19.2	*	11.7
Farson															
P	0.4	0.5	0.5	0.7	1.0	0.9	0.6	0.6	0.7	0.7	0.4	0.3	7.1	*	1.9
PET	0.0	0.0	0.0	0.9	2.5	3.7	4.8	4.1	2.5	1.1	0.0	0.0	19.6	*	11.7
Green River															
P	0.5	0.5	0.7	1.0	1.2	0.9	0.6	0.8	0.7	1.0	0.5	0.4	8.7	2.5	3.4
PET	0.0	0.0	0.1	1.3	2.8	4.1	5.3	4.6	2.9	1.4	0.0	0.0	21.6	14.7	17.7
Kemmerer															
P	0.7	0.7	0.7	0.7	1.1	1.0	0.7	0.8	0.6	0.7	0.7	0.7	9.1	*	2.9
PET	0.0	0.0	0.0	1.0	2.5	3.5	4.6	4.0	2.5	1.2	0.0	0.0	19.4	*	13.7
Rock Springs Airport															
P	0.5	0.6	0.6	1.0	1.1	0.8	0.6	0.7	0.7	1.0	0.6	0.4	8.7	2.8	3.6
PET	0.0	0.0	0.0	1.0	2.6	3.9	5.2	4.6	2.8	1.3	0.0	0.0	21.4	15.8	18.0

P = Precipitation

PET = Potential Evapotranspiration

*No regular freeze-free period.

Source: Normals of Evapotranspiration in Wyoming (U.S. Department of Commerce - U.S. Soil Conservation Service)

DESCRIPTION OF AIR QUALITY

The southwestern Wyoming ES region lies within the Wyoming Intrastate Air Quality Control Region (AQCR), as designated by the U.S. Environmental Protection Agency (EPA), and comprises the state's northeastern, northern, western, and southwestern borderlands. Currently, National Ambient Air Quality Standards (NAAQS) exist for total suspended particulates (TSP), sulfur dioxide (SO_2), carbon monoxide (CO), photochemical oxidants (O_x), and nitrogen oxides (NO_x). Additionally, there is a federal guideline for ambient nonmethane hydrocarbon (HC) levels. The State of Wyoming also has air quality standards, which include regulations applicable to the above pollutants, as well as settleable particulates, coefficient of haze, sulfates, hydrogen sulfide, and fluorides.

The activities associated with the proposed mining would generate both vehicular emissions and fugitive dusts (particulates). Vehicular emissions could alter ambient CO, NO_x, HC, and SO_2 levels; and fugitive dust emission would have an impact on ambient TSP levels. Any gaseous emissions associated with proposed mining activities should have their greatest impact closest to the mine. However, the proposed expansion of the Naughton Power Plant and the expansion of the Jim Bridger Power Plant could affect the ambient levels of SO_2 and NO_x in addition to those for TSP. Consequently, the following analysis of present air quality will primarily address the ambient concentrations of TSP, since each activity (the mining and burning of coal as well as increased vehicular travel) can have a direct impact on the environmental levels of this pollutant. A less detailed analysis of the existing levels of the gaseous pollutants (SO_2, NO_2) will be given to describe expected baseline concentrations throughout the ES region.

The ensuing paragraphs discuss the following topics:

- the federal and Wyoming ambient air quality standards for TSP, SO_2, and NO_2 with aspects of the Clean Air Act Amendments of 1977 pertinent to the present analysis;
- the existing levels (1975) of TSP in the ES region;
- a justification for the use of 1975 data;
- the existing levels (1976) of SO_2 and NO_2 in the ES region;
- horizontal visibility; and
- expected future pollutant levels without including the proposed actions.

Air Quality Standards and Regulations

The Clean Air Act of 1970 specified that each state would be responsible for ensuring air quality within its borders and for specifying the way air quality would be achieved and maintained (ERT 1977).

On 30 April 1971, the EPA promulgated primary and secondary NAAQS (Federal Register 1971). The primary standards were established to protect human health; whereas the secondary standards were established to protect the public welfare from any known or anticipated adverse effects. The primary and secondary 24-hour or short-term standards for TSP, not to be exceeded more than once per year, are 260 and 150 $\mu g/m^3$, respectively. The annual or long-term limits are 75 and 60 $\mu g/m^3$. These are, respectively, the primary standard and a guideline rather than a secondary standard. An annual TSP concentration is defined as the geometric mean. The NAAQS for SO_2 are 1,300 $\mu g/m^3$, 365 $\mu g/m^3$, and 80 $\mu g/m^3$ for the 3-hour maximum, 24-hour maximum, and annual arithmetic mean, respectively. The 3-hour maximum is a secondary standard; the other two are primary standards. The short-term standards are not to be exceeded more than once per year. The annual limit established for NO_2 is 100 $\mu g/m^3$. The Clean Air Act Amendments of 1977 charged EPA with promulgating a 3-hour (or less) primary standard for NO_2 unless there is "no significant evidence" that such a standard is needed to protect public health.

On 22 January 1972, the State of Wyoming adopted air quality regulations that differed slightly from NAAQS. The state annual standard for TSP is 60 $\mu g/m^3$ (geometric mean) and the 24-hour standard, not to be exceeded more than once per year, is 150 $\mu g/m^3$. Wyoming SO_2 standards are also more strict than federal regulations. The annual standard is 60 $\mu g/m^3$ (arithmetic mean) and the 24-hour standard, not to be exceeded more than once a year, is 260 $\mu g/m^3$. The state limit for NO_2 is the same as the NAAQS for NO_2. Table R2-26 summarizes the State of Wyoming and federal ambient air quality standards for these pollutants.

The Clean Air Act of 1970 mandated division of each state and appropriate interstate area into Air Quality Control Regions (AQCRs). The Clean Air Act Amendments of 1977 require the states to identify regions and parts of regions that do and do not meet the NAAQS by 7 December 1977, thereby determining which areas are governed by Prevention of Significant Deterioration (PSD) and nonattainment (NA) requirements, respectively (ERT 1977). In January 1972, the State of Wyoming classified the Wyoming Intrastate AQCR as Priority III for TSP, meaning that ambient air quality within this region was better than the state standards.

On 7 December 1977, the State of Wyoming submitted its initial list of two NA areas in the southwestern Wyoming ES region: the City of Rock Springs and the trona mining area, 6 miles north of Green River. Within

TABLE R2-26

STATE OF WYOMING AND NATIONAL AMBIENT AIR QUALITY STANDARDS FOR CONCENTRATIONS OF TSP, SO_2, AND NO_2

Pollutant	Averaging Time	Standard ($\mu g/m^3$) Federal Primary*	Federal Secondary**	Wyoming
TSP	Annual†	75	60§	60
	24-Hour††	260	150	150
SO_2	Annual§§	80		60
	24-Hour††	365		260
	3-Hour††		1,300	1,300
NO_2	Annual§§	100	100	100

*Requisite to protect human health.

**Requisite to protect the public welfare from any known or anticipated adverse effects.

†Geometric Mean

††Not to be exceeded more than once per year.

§Guideline

§§Arithmetic Mean

each of these areas, monitors have recorded violations of the state and federal annual TSP standards (Raffelson 1978). The EPA has modified the list to include only the trona mining area, since TSP violations in Rock Springs are very localized, caused by fugitive dust, and not representative of the area as a whole (Russell 1978). A state may review and revise its list of NA areas periodically, and the governor may redesignate AQCRs "for purposes of efficient and effective air quality maintenance" (ERT 1977).

The Clean Air Act Amendments of 1977 strengthened the enforcement mechanisms for PSD and for attainment of standards in NA areas. Nonattainment regulations apply to states containing areas in violation of the NAAQS.

The original mid-1975 deadline for attainment of primary air quality standards has largely slipped, and Congress has established a stringent new time table. Each state must submit by January 1979 a revised State Implementation Plan (SIP) that mandates how primary standards will be achieved by 1982. If a state fails to submit an approval plan to EPA, no permit for a new or modified major plant can be issued after 1 July 1979 (ERT 1977).

PSD regulations apply to areas where air quality meets the state standards. These levels, designated for Class I, II, and III areas, are set to regulate incremental increases of TSP and SO_2 from new sources within Priority III regions according to the amount of energy or industrial growth desired. The following classes of desired growth were established by the EPA:

- Class I - areas where nearly any air quality deterioration would be considered significant, thus allowing little or no energy or industrial development.
- Class II - areas where deterioration that would normally accompany moderate, well-controlled growth would not be considered significant.
- Class III - areas where deterioration would be permitted to allow concentrated or very large scale energy or industrial development as long as the secondary NAAQS are not exceeded.

Construction of new facilities in those areas meeting NAAQS is controlled by interim rules and revised plans. At present, PSD rules apply only to SO_2 and TSP; however, the EPA is required to promulgate regulations for other criteria pollutants such as photochemical oxidants by August 1979 (ERT 1977).

The State of Wyoming was initially classified a Class II area with the exception of five wilderness areas and two national parks larger than 6,000 acres, which have been classified manditory Class I. Of these seven Class I areas, only Bridger Wilderness Area is located near the ES region (see Map R2-14). In addition to the existing Class I area, three proposed wilderness areas near the ES region could gain Class I status in the near future: Popoagie and Flaming Gorge National Recreation Area in Wyoming, and High Uinta Primitive Area in Utah (Connor 1978). At present, neither the state of Wyoming nor the Wind River Indian Reservation has definite plans to reclassify any other areas of the state (Raffelson 1978).

Comparison of Ambient TSP Levels Measured During 1975 and 1976

Air quality data collected in southwest Wyoming during 1975 were used to establish baseline conditions in the 1977 ES. An additional year of data were collected at these sites in 1976 and were available as an updated data base if found to differ significantly from the 1975 data. Therefore, TSP data for 1975 and 1976 were statistically compared for each of several state and private monitoring sites to determine any significant differences in TSP concentrations between the two years. An F-test was used to test the assumption that the variance of the 1976 data did not differ from the variance of the 1975 data at each monitoring site. Results of the F-test are presented in Table R2-27 and possible explanations for the differences between 1975 and 1976 TSP concentrations follow.

The F-test results indicate a significant difference between 1975 and 1976 TSP concentrations at four state monitoring sites: Green River, Rock Springs (Logan), and Rock Springs (Alder) data exhibit a significant difference at the 95 and 99% confidence levels, whereas Granger data exhibit a significant difference at the 95% confidence level only. A comparison of the annual geometric means for 1975 and 1976 TSP concentrations at each of these four sites indicates that TSP levels rose in 1976 at the Granger and Rock Springs (Logan) monitoring sites and dropped in 1976 at the Rock Springs (Alder) and Green River monitoring sites.

The Wyoming Department of Environmental Quality was consulted (Blackwell 1978) concerning the differences between 1975 and 1976 TSP data from the four state monitors. The DEQ provided some possible explanations for the changes, noted as follows.

- Green River, Clause Residence (A-9) - this monitor was moved in 1976 from a windy area on the open prairie south to a residential area that is more protected from wind and dust.

- Rock Springs, Logan Residence (A-10) - this monitor is in a residential area. During 1976, traffic was known to increase in the vicinity of this high volume (hi-vol) sampler.

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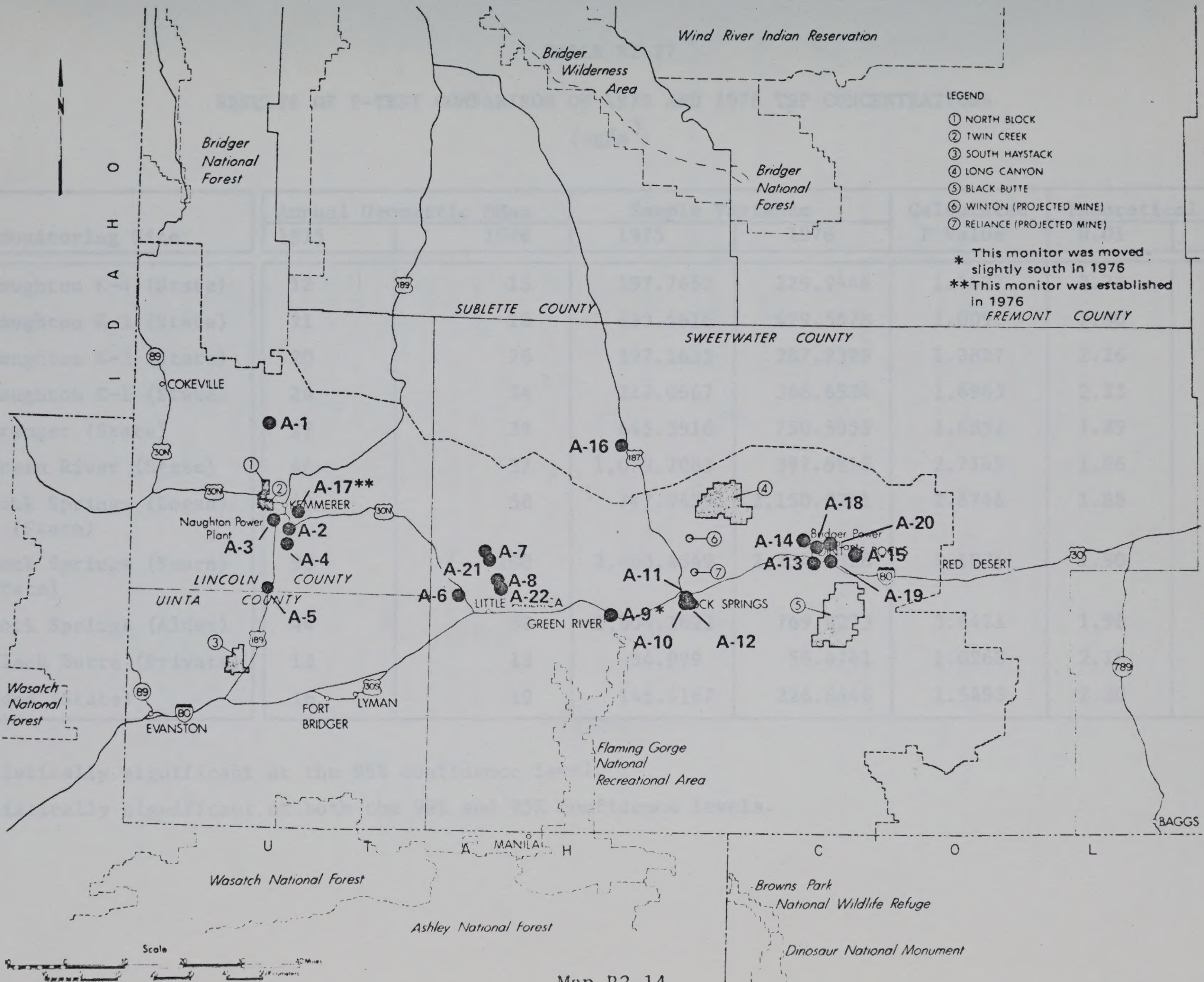
N
IDAHO
Wind River Indian Reservation
Bridger Wilderness Area
Bridger National Forest
Bridger National Forest
LEGEND
① NORTH BLOCK
② TWIN CREEK
③ SOUTH HAYSTACK
④ LONG CANYON
⑤ BLACK BUTTE
⑥ WINTON (PROJECTED MINE)
⑦ RELIANCE (PROJECTED MINE)
* This monitor was moved slightly south in 1976
** This monitor was established in 1976
SUBLETTE COUNTY
FREMONT COUNTY
SWEETWATER COUNTY
LINCOLN COUNTY
UINTA COUNTY
COKEVILLE
A-1
A-16
A-17**
KEMMERER
Naughton Power Plant
A-2
A-3
A-4
A-5
A-6
A-7
A-8
A-21
A-22
LITTLE AMERICA
A-9*
A-10
A-11
A-12
A-13
A-14
A-15
A-18
A-19
A-20
Bridger Power Plant
POINT OF ROCKS
ROCK SPRINGS
GREEN RIVER
RED DESERT
Wasatch National Forest
EVANSTON
FORT BRIDGER
LYMAN
Flaming Gorge National Recreational Area
MANILA
UTAH
COLO
BAGGS
Browns Park National Wildlife Refuge
Dinosaur National Monument
Wasatch National Forest
Ashley National Forest
Scale
40 Miles
Kilometers
89
30N
189
187
30S
80
30
789

Map R2-14

Location of Air Quality Monitors in Southwestern Wyoming

TABLE R2-27

RESULTS OF F-TEST COMPARISON OF 1975 AND 1976 TSP CONCENTRATIONS

($\mu g/m^3$)

Monitoring Site	Annual Geometric Mean		Sample Variance		Calculated F Value	Theoretical F Value	
	1975	1976	1975	1976		0.01	0.05
A-1 Naughton K-4 (State)	12	15	197.7662	229.9446	1.1627	2.78	2.04
A-2 Naughton K-3 (State)	21	18	433.4616	429.5678	1.009	2.30	1.79
A-3 Naughton K-2 (State)	20	26	397.1635	287.2329	1.3827	2.26	1.77
A-4 Naughton K-1 (State)	24	34	217.0667	368.6534	1.6983	2.23	1.75
A-6 Granger (State)	27	39	445.3916	750.5959	1.6852	1.89	1.57*
A-9 Green River (State)	46	37	1,079.7083	397.6918	2.7149	1.96	1.60**
A-10 Rock Springs (Logan) (State)	40	58	747.9439	2,150.0281	2.8746	1.88	1.56**
A-11 Rock Springs (Fearn) (State)	90	100	2,463.4549	2,234.6318	1.1024	1.90	1.58
A-12 Rock Springs (Alder)	44	38	2,804.1623	769.9273	3.6421	1.98	1.62**
A-13 Black Butte (Private)	13	13	54.999	56.4741	1.0268	2.16	1.72
A-16 Eden (State)	16	19	146.4167	226.8446	1.5493	2.30	1.78

*Statistically significant at the 95% confidence level.

**Statistically significant at both the 99% and 95% confidence levels.

- Rock Springs, Alder Residence (A-12) - the reason for the decrease in 1976 data at this site is not understood. The monitor is on the outskirts of town. Road construction, which may have caused a redistribution of normal traffic patterns away from the area, was initiated in the area in 1976.

- Granger, Lindsley Residence (A-6) - in 1976 construction activity in the vicinity of this monitor increased. As a result, traffic and other associated activities would also have increased, possibly causing higher TSP levels.

From the statistical comparison of 1975 and 1976 TSP data, it was concluded that in general the regional air quality measured by the monitors did not change significantly from one year to the next. The five private monitors and half of the state monitors showed no statistical difference between the data of the two years. The changes observed at the four remaining state monitors were thought to result from events discussed above.

Existing Ambient Air Quality

To describe air quality, the ES region has been divided into three subregions (called portions) as follows:

• Western	this portion is bounded on the east by the Bridger Basin or on a north/south line through Lyman, Wyoming. The monitoring data collected in the western portion is descriptive of Kemmerer and its surroundings (see Map R2-14).
• Central	this portion includes the urban sites of Rock Springs and Green River, as well as the industrial area known as the trona patch in the vicinity of Little America, Wyoming. Most of the air quality monitors in this area were installed to survey urban or industrial environments. However, its geographic character is primarily rural like the other subregions even though at times the central portion is referred to as urban or industrial.
• Eastern	this portion extends eastward from the City of Rock Springs. Most of the monitoring data in this area is collected in the vicinity of Point of Rocks, Wyoming and the Jim Bridger Power Plant. Again, reference to it as an industrial area is only used in relative terms since the majority of the region is rural.

The monitoring data used in this analysis were made available through the courtesy of several private corporations and government agencies. A telephone survey was made to inquire about instrument exposure, quality assurance procedures in data handling, and the purpose for choosing each monitoring site. However, the large volume of data and time constraints prevented a detailed secondary screening process to isolate nonrepresentative data.

The ensuing paragraphs describe the regional air quality by delineating expected pollutant concentrations for the different subregions. However, use caution when interpreting pollutant concentrations at points of observation (especially extreme values) and in extrapolating these values to other locales in the ES region.

Map R2-14 shows the locations of TSP, SO_2, and NO_2 monitors in the ES region. The purpose of each monitor as well as its location or environment is listed in Table R2-28.

Total Suspended Particulates

The existing level of air quality in the ES region can be defined as inversely proportional to the TSP levels in the area. In general, the monitored TSP levels are not high, thus regional air quality is quite good. Fugitive dust from natural sources, as well as particulates generated by industrial operations, construction, and unpaved roads, generally increase the ambient levels, especially during the dry, windy seasons. These levels increase during periods of higher emissions and limited mixing or stable atmospheric conditions when the dispersion of fugitive dust is inhibited. Particulate levels appear high in specific areas of residential housing, heavy commercial traffic, ongoing construction, active above-ground mining operations, and/or power generating facilities, especially when these levels, caused by a specific industrial source, are compared to rural or background levels. Map R2-14 shows TSP monitor locations. The peak concentrations measured at the sensors are summarized in Table R2-29. Maps R2-15 and R2-16 illustrate the spatial distribution of these data for the analysis year 1975.

The western portion of the ES region includes both industrial and rural areas. The TSP levels in this portion are quantified by data obtained at monitors A-1, A-2, A-3, A-4, and A-5. Particulate levels measured in the vicinity of Kemmerer, the only industrialized area in the western portion of the ES region, indicate that this is the area of heaviest particulate impact. The samples obtained at monitors A-2, A-3, and A-4 represent background TSP levels in an industrialized environment, as these sensors were established to monitor the impact from existing coking, mining, and power generating facilities (Ursenbach 1976). The maximum 24-hour TSP concentrations measured at these sites in 1975 range from 103 $\mu g/m^3$ (69% of the federal secondary standard and the state standard) to 69 $\mu g/m^3$ (less than half of these standards). The peak annual concentration (geometric mean) of 24 $\mu g/m^3$ represents 40% of the state and federal limit of 60 $\mu g/m^3$ and 32% of the federal primary standard.

TABLE R2-28

AIR QUALITY MONITORS IN SOUTHWESTERN WYOMING

Site Code	Monitor	Location	County	Portion of Region	Monitoring Purpose/ Environment	Private or State Operation	Pollutants Monitored at Site
A-1	Naughton, K-4	Kemmerer	Lincoln	West	Background/Rural	Private	TSP
A-2	Naughton, K-3	Kemmerer	Lincoln	West	Impact/Industrial	Private	TSP, SO_2
A-3	Naughton, K-2	Kemmerer	Lincoln	West	Impact/Industrial	Private	TSP, SO_2
A-4	Naughton, K-1	Kemmerer	Lincoln	West	Impact/Industrial	Private	TSP, SO_2
A-5	South Haystack		Lincoln	West	Background/Rural	Private	TSP
A-6	Don Lindsley*	Granger	Sweetwater	Central	Background/Residential	State	TSP
A-7	Texas Gulf No. 1	Little America	Sweetwater	Central	Background/Industrial	Private	TSP
A-8	FMC - Site A	Little America	Sweetwater	Central	Background/Industrial	Private	TSP
A-9**	Larry Clause*	Green River	Sweetwater	Central	Background/Residential	State	TSP
A-10	John Logan*	Rock Springs	Sweetwater	East	Background/Residential	State	TSP
A-11	Lyman Fearn*	Rock Springs	Sweetwater	East	Impact/Center City	State	TSP, SO_2
A-12	Robert Alder*	Rock Springs	Sweetwater	East	Background/Residential	State	TSP
A-13	Black Butte		Sweetwater	East	Background/Rural	Private	TSP
A-14	Bridger-Superior Wells	Point of Rocks	Sweetwater	East	Impact/Industrial	Private	TSP, SO_2, NO_2
A-15	Bridger-Microwave	Point of Rocks	Sweetwater	East	Impact/Industrial	Private	TSP, SO_2, NO_2
A-16	Sellers*	Eden	Sweetwater	North	Background/Rural	State	TSP
A-17†	Kemmerer	Kemmerer	Lincoln	West	Background/Rural	State	TSP, SO_2, NO_2
A-18	Bridger-Plant	Point of Rocks	Sweetwater	East	Impact/Industrial	Private	TSP, SO_2, NO_2
A-19	Bridger-Point of Rocks	Point of Rocks	Sweetwater	East	Impact/Industrial	Private	TSP, SO_2, NO_2
A-20	Bridger-Bluff Station	Point of Rocks	Sweetwater	East	Impact/Industrial	Private	TSP, SO_2, NO_2
A-21†	FMC-Site C	Little America	Sweetwater	Central	Impact/Industrial	Private	SO_2
A-22†	Texas Gulf-Site 4	Little America	Sweetwater	Central	Background/Industrial	Private	SO_2

*Private Residences

**Monitor A-9 was moved slightly south in 1976.

†Monitors established in 1976.

TABLE R2-29

PARTICULATE CONCENTRATIONS MEASURED IN SOUTHWESTERN WYOMING*
($\mu g/m^3$)

Site Code	Sampling Year	Number of Observations**	Maximum 24-Hour Concentration	2nd Highest 24-Hour Concentration	Number of Violations of the Federal 24-Hour Standards†		Annual Geometric Mean
					Primary	Secondary	
A-1	1973	32	114	92	0	0	16
	1974	23	47	NA	0	0	22
	1975	22	59	44	0	0	12
	1976	27	51	47	0	0	15
A-2	1973	16	46	42	0	0	21
	1974	41	71	NA	0	0	34
	1975	45	103	86	0	0	21
	1976	30	74	71	0	0	18
A-3	1973	14	50	35	0	0	22
	1974	31	91	NA	0	0	39
	1975	40	83	77	0	0	20
	1976	32	75	61	0	0	26
A-4	1973	23	65	48	0	0	24
	1974	37	125	NA	0	0	53
	1975	46	69	58	0	0	24
	1976	33	78	77	0	0	34
A-5	1976	27**	68	64	0	0	28
A-6	1973	46	114	109	0	0	43
	1974	53	209	195	0	2	54
	1975	57	93	87	0	0	27
	1976	57	150	101	0	0	39
A-7	1974	49	59	43	0	0	21
	1975	60	53	45	0	0	16
	1976	59	57	53	0	0	19
A-8	1974	34	126	91	0	0	35
	1975	92	143	99	0	0	28
	1976	37	73	70	0	0	27
A-9	1975	49	119	115	0	0	46††
	1976	58	84	80	0	0	37††
A-10	1975	59	131	111	0	0	40
	1976	58	259	218	0	2	58
A-11	1972	45	271	240	0	1	119
	1973	50	321	277	3	20	118
	1974	52	347	308	7	18	115
	1975	57	231	207	0	11	90
	1976	58	248	218	0	9	100
A-12	1975	46	283	155	0	1	44
	1976	54	145	145	0	0	38
A-13	1975	34	43	26	0	0	13
	1976	60	37	33	0	0	13
A-14	1971-1972	NA	NA	NA	NA	NA	23
	1972-1973	NA	NA	NA	NA	NA	21
	1973-1974	NA	NA	NA	NA	NA	20
	1974-1975	71	167	162	0	1	24
	1975-1976	60	100	87	0	0	32
A-15	1971-1972	NA	NA	NA	NA	NA	31
	1972-1973	NA	NA	NA	NA	NA	22
	1973-1974	NA	NA	NA	NA	NA	14
	1974-1975	69	64	57	0	0	14
	1975-1976	55	95	91	0	0	19
A-16	1975	28	63	39	0	0	16
	1976	52	94	50	0	0	19
A-17	1976	15	45	30	0	0	13
A-18	1971-1972	NA	NA	NA	NA	NA	53
	1972-1973	NA	NA	NA	NA	NA	61
	1973-1974	NA	NA	NA	NA	NA	80
	1974-1975	67	805	787	5	13	87
	1975-1976	56	1135	526	9	16	56

TABLE R2-29 (continued)

PARTICULATE CONCENTRATION MEASURED IN SOUTHWESTERN WYOMING*

($\mu g/m^3$)

Site Code	Sampling Year	Number of Observations**	Maximum 24-Hour Concentration	2nd Highest 24-Hour Concentration	Number of Violations of the Federal 24-Hour Standards[†]		Annual Geometric Mean
					Primary	Secondary	
A-19	1974-1975	41	121	112	0	0	23
	1975-1976	54	59	48	0	0	25
A-20	1974-1975	15	76	47	0	0	33
	1975-1976	55	303	113	0	1	32

NA means not available

* See Table R2-28 and Map R2-14 for description of monitor location and environment.

**Samples were obtained approximately every six days.

[†] See Table R2-26.

[††] Average of four quarterly geometric means.

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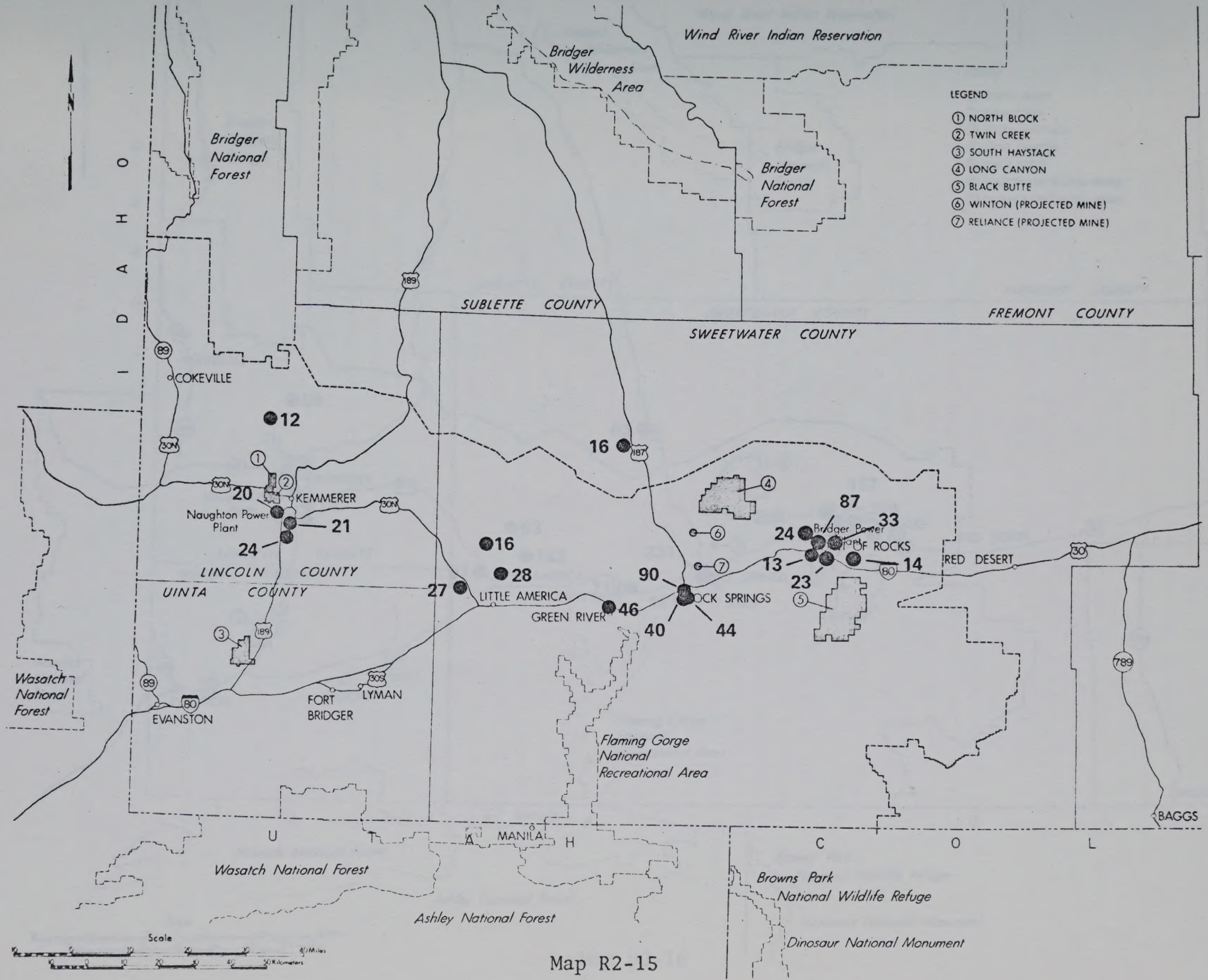
Wind River Indian Reservation
Bridger Wilderness Area
Bridger National Forest
Bridger National Forest
LEGEND
① NORTH BLOCK
② TWIN CREEK
③ SOUTH HAYSTACK
④ LONG CANYON
⑤ BLACK BUTTE
⑥ WINTON (PROJECTED MINE)
⑦ RELIANCE (PROJECTED MINE)
IDAHO
SUBLETTE COUNTY
FREMONT COUNTY
SWEETWATER COUNTY
COKEVILLE
12
16
20
KEMMERER
Naughton Power Plant
21
24
LINCOLN COUNTY
UINTA COUNTY
16
28
27
LITTLE AMERICA
GREEN RIVER
46
90
ROCK SPRINGS
40
44
87
33
24
Bridger Power Plant
POINT OF ROCKS
13
14
23
RED DESERT
EVANSTON
FORT BRIDGER
LYMAN
Wasatch National Forest
Flaming Gorge National Recreational Area
BAGGS
UTAH
MANILA
COLO
Wasatch National Forest
Ashley National Forest
Browns Park National Wildlife Refuge
Dinosaur National Monument
Scale
Miles
Kilometers

Map R2-15

1975 Annual Geometric Mean TSP Concentrations Monitored in Southwestern Wyoming

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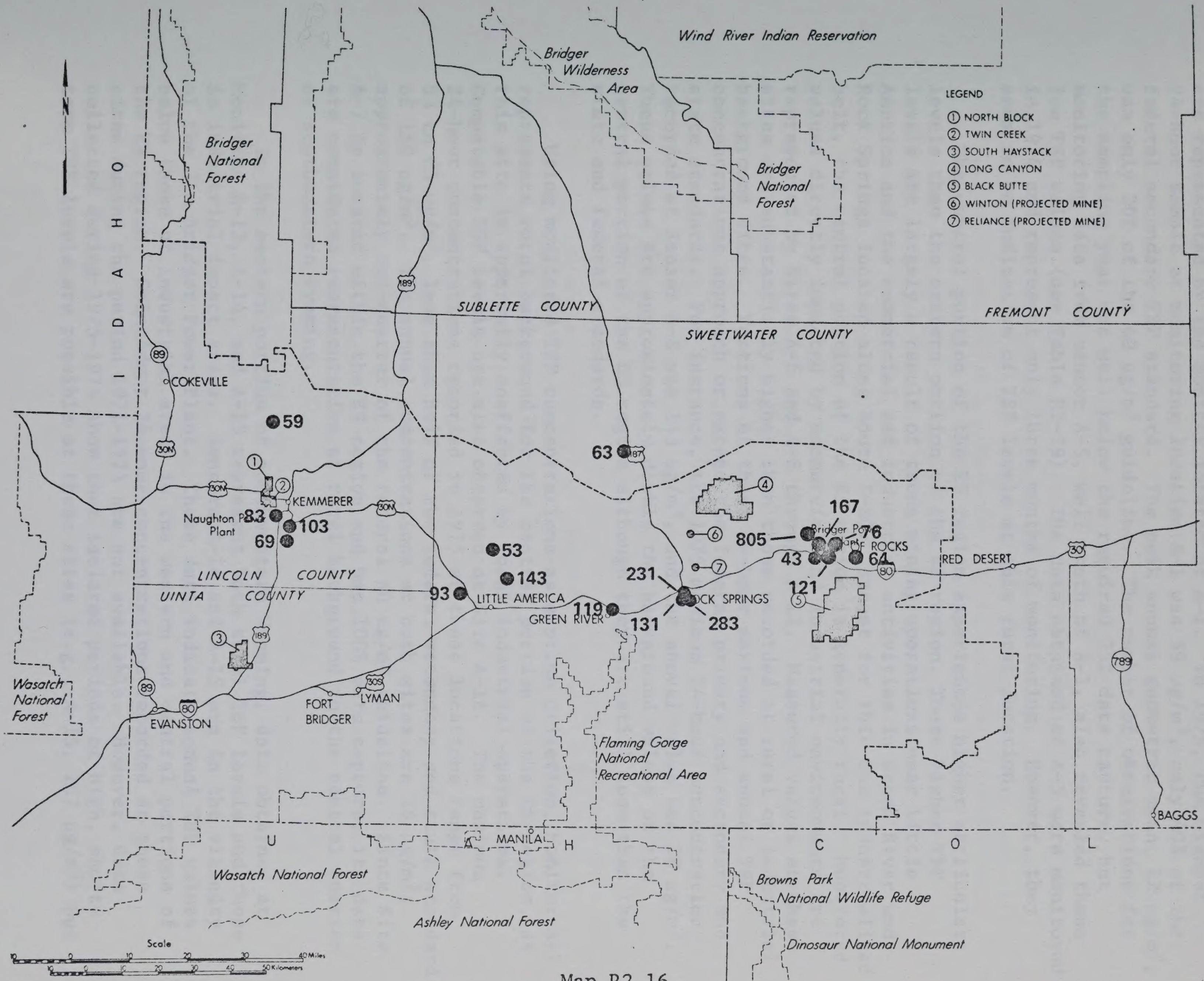

Wind River Indian Reservation
Bridger Wilderness Area
Bridger National Forest
Bridger National Forest
LEGEND
① NORTH BLOCK
② TWIN CREEK
③ SOUTH HAYSTACK
④ LONG CANYON
⑤ BLACK BUTTE
⑥ WINTON (PROJECTED MINE)
⑦ RELIANCE (PROJECTED MINE)
N
IDAHO
SUBLETTE COUNTY
FREMONT COUNTY
SWEETWATER COUNTY
LINCOLN COUNTY
UINTA COUNTY
COKEVILLE
59
63
KEMMERER
Naughton Power Plant
83
103
69
53
143
93
LITTLE AMERICA
GREEN RIVER
119
231
131
283
ROCK SPRINGS
805
167
Bridger Power Plant
76
43
64
POINT OF ROCKS
121
RED DESERT
EVANSTON
FORT BRIDGER
LYMAN
Wasatch National Forest
Flaming Gorge National Recreational Area
MANILA
BAGGS
UTAH
COLORADO
Wasatch National Forest
Ashley National Forest
Browns Park National Wildlife Refuge
Dinosaur National Monument
Scale
10 0 10 20 30 40 Miles
10 0 10 20 30 40 50 Kilometers
89
30N
189
187
80
30S
30
789

Map R2-16

1975 Maximum 24-Hour TSP Concentrations Monitored in Southwestern Wyoming

In the western portion of the ES region, rural background values are represented by the monitor located at A-1. In 1975, the highest 24-hour sample at monitoring location A-1 was 59 µg/m^3, only 40% of the federal secondary TSP standard. The peak annual geometric mean, 12 µg/m^3, was only 20% of the 60 µg/m^3 guideline. The number of observations for the sampling year was well below the required 75% data capture, but monitoring data from sensor A-5, well south of A-1, also revealed these low TSP values (see Table R2-29). The data obtained at A-5 were monitored in 1976 and represent only three months of monitoring. However, they seem to be indicative of TSP levels at this rural location.

The central portion of the ES region experiences higher particulate levels than the eastern portion of the ES region. These higher TSP levels are largely a result of trona mining operations near Little America and the commercial and industrial activities in Green River and Rock Springs located along Route I-80. Except for this one industrialized belt, the central portion of the ES region is generally rural. Monitored values directly impacted by commercial and industrial environments are represented by Sites A-6 and A-8 through A-12. Measured values at these sites are substantially higher than those recorded at rural or industrial background sites. Portions of these 24-hour maximum and annual TSP concentrations approach or exceed the federal primary and secondary and state standards. For instance, the 1975 maximum 24-hour concentration recorded at Sensor A-8 was 143 µg/m^3, and the annual value was 28 µg/m^3. These values are approximately double the background values of the central portion of the ES region although they are still less than the state and federal standards.

Using monitored TSP concentrations as a prime criterion, Monitor A-7 represents rural background for the central portion of the ES region, as this site is apparently unaffected by local industrial operations. Comparable TSP levels are also observed at Site A-16. The maximum 24-hour concentrations recorded in 1975 at these locations range from 53 to 63 µg/m^3, less than half of the federal secondary and state standard of 150 µg/m^3. The annual concentrations at both sites are 16 µg/m^3, approximately one-quarter of the federal 60 µg/m^3 guideline. Since Site A-7 is located within the ES region and has 100% data capture, its data are considered representative of rural background in the central portion of southwestern Wyoming.

In the eastern portion of southwestern Wyoming, data obtained at Monitors A-13, A-14, and A-15 represent both rural TSP levels and those in industrial impact areas. Sensors A-14 and A-15 are in the vicinity of the Jim Bridger Power Plant. These data indicate annual TSP values below those of industrial areas in the western and central portions of the ES region. Coincident 24-hour concentrations recorded at these sites during the period 1971-1973 are not available. However, data collected during 1975-1976 show that isolated periods of high, short-term TSP levels are possible at these sites (e.g., A-15, 167 µg/m^3) but

long-term concentrations appear more rural than industrial in nature. Site A-13 represents rural background TSP levels in the eastern portion of the ES region. Concentrations measured at this nonindustrial site in 1975 indicate an annual value of 13 μg/m^3 and a maximum 24-hour value of 43 μg/m^3. All rural areas in the eastern portion of the ES region are expected to experience TSP levels similar to site A-13.

In summary, the air quality in rural areas of southwestern Wyoming is good. Industrial and commercial environments across the ES region experience higher particulate concentrations at times, but are generally within the state and federal standards. It is important to note that those sites with recorded concentrations exceeding the air quality standards are recording TSP levels directly influenced by industrial activities, and data obtained from these sites do not represent the total ES region.

Sulfur Dioxide

Until recently, the number of SO_2 monitors throughout the ES region was quite limited. However, in 1976 the number of stations was increased to more than twelve, and all could record ambient SO_2 concentrations in 24-hour increments. SO_2 monitors selected to represent the general air quality in the western, central, and eastern portions of the ES region are identified in Table R2-28. The purpose of each sensor, as well as its environment, is also listed. Table R2-30 presents where available the highest and second highest 3- and 24-hour average SO_2 concentrations as well as annual averages for each of the sites. As indicated, recorded 3-, 24-hour, and annual SO_2 concentrations in southwestern Wyoming are not generally high. The highest concentrations are generated by industrial operations, such as power plants, and are quite localized. The available data indicate that in no instance do the ambient levels exceed federal or Wyoming air quality standards.

In the western portion of the ES region, all SO_2 monitors (A-2, A-3, and A-4) are located in the vicinity of Kemmerer, the only industrial center in the area. These sensors record SO_2 levels in an industrialized environment directly influenced by emissions from coking, mining, and power generating operations (Ursenbach 1976). The maximum 24-hour SO_2 concentrations measured at these sites in 1975 to 1976 range from 14 μg/m^3 (4% of the federal and 5% of the state standard) to 26 μg/m^3 (7% of the federal and 10% of the state standard). Similarly, the 3-hour peaks are less than 10% of the state and federal standard of 1,300 μg/m^3. The peak annual concentration (arithmetic mean) of 3 μg/m^3 represents 4% and 5% of the federal and state standards, respectively.

Since ambient SO_2 concentrations are more dependent on local anthropogenic sources than are TSP levels, the rural portions of the ES region not directly affected by an isolated source should more clearly indicate lower SO_2 concentrations. In 1976, the state installed an SO_2

TABLE R2-30

CONCENTRATIONS OF SO_2 MEASURED IN SOUTHWESTERN WYOMING
($\mu g/m^3$)

Site	Sampling Year	No. Observations		Max. Conc.		2nd Highest Conc.		No. Violations of the Federal Std.		Annual Arithmetic Mean
		1-Hour	Daily	3-Hour	24-Hour	3-Hour	24-Hour	3-Hour	24-Hour	
A-2	1975-1976	8491	350	115	24	86	21	0	0	2
A-3	1975-1976	7514	304	89	14	89	11	0	0	0.7
A-4	1975-1976	8056	331	105	26	100	22	0	0	3
A-11*	1972		39		20		20		0	4
	1973		42		12		8		0	3
	1974		46		10		5		0	1
	1975		59		10		10		0	2
	1976		36		9		8		0	1
A-14**	1974-1975		NA		NA		NA		NA	<2.6 (9 months)†
	1975-1976		NA		NA		NA		NA	2.6
A-15**	1974-1975		NA		NA		NA		NA	<2.6 (9 months)
	1975-1976		NA		NA		NA		NA	2.6
A-17*	1976		10		5		2		0	1
A-18	1974-1975		NA		NA		NA		NA	<2.6 (9 months)
	1975-1976		NA		NA		NA		NA	2.6
A-19**	1974-1975		NA		NA		NA		NA	<2.6 (6 months)
	1975-1976		NA		NA		NA		NA	2.6
A-20**	1974-1975		NA		NA		NA		NA	5.2 (3 months)
	1975-1976		NA		NA		NA		NA	10.4
A-21	1974	226	-	309	131	302	128	0	0	NA
	1975	6704	-	197	98	163	77	0	0	NA
	1976	5102	-	197	99	137	62	0	0	NA
A-22*	1976		9		3		3		0	NA

NA means not available.

*SO_2 gas bubbler providing 24-hr average alone

**Short-term data not readily available

†Sampling duration

SW Ch. 2 Tech.
Sec. AQ
ERT 4-3-78
Cd. 2382 Pg. 26

gas bubbler east of Kemmerer (Site A-17) to monitor background SO_2 levels. The 24-hour concentrations monitored at this site are lower than those previously mentioned, but the ten observations are insufficient and seasonally biased to be considered significant. However, that the peak 24-hour SO_2 concentrations observed are on the order of the resolution of the instrument threshold suggests that levels in these rural areas should be minimal in comparison to ambient standards.

Sulfur dioxide monitors in the central portion of the ES region are situated near Little America in the basin referred to as the trona patch. Monitor A-22 is located slightly northeast of Little America on an isolated mesa to the southeast of the Texas Gulf Plant. Data collected at this sensor should represent the general background levels of this industrial area and not the direct plant emissions. Only nine observations were made at this station in 1976, giving insufficient data from which to draw conclusions. However, as with Site A-17, preliminary data from A-22 suggests that background SO_2 levels in the area should be safely below short-term standards, with peak values at or below the resolution of the instrument.

Northwest of monitor A-22 is the FMC monitor A-21. This sensor is positioned 3,000 feet to the east of the FMC plant and was established to measure SO_2 from the new FMC boiler. The maximum 24-hour SO_2 concentration recorded in 1976 is 99 $\mu g/m^3$, 27% of NAAQS and 38% of the state standard. The peak annual concentration for the site is not available at this time.

Another state SO_2 bubbler (A-11) is located in the City of Rock Springs. It was installed to survey ambient SO_2 levels in this central Wyoming population district. The peak 24-hour concentration recorded at this site was 20 $\mu g/m^3$. The annual mean in that year was 4 $\mu g/m^3$, only 5% of the corresponding federal standards.

The SO_2 monitors in the eastern portion of the ES region are located in the vicinity of the Jim Bridger Power Plant. These samplers collect data on plant emissions. The Bluff Station (A-20), is situated directly downwind (east) of the Jim Bridger Power Plant; thus, it records the greatest levels of SO_2 in the Bridger network. The maximum 24-hour concentration measured in 1976 at A-20 is 158 $\mu g/m^3$ (43% and 61% of federal and state standards, respectively). The peak annual concentration (arithmetic mean) is 10.4 $\mu g/m^3$ (13% of federal and 17% of Wyoming standards). Annual concentrations at A-14, A-15, A-18, and A-19 were all at or below 2.6 $\mu g/m^3$.

In summary, ambient SO_2 levels are generally very low throughout the ES region. On occasion, at certain locations, short-term SO_2 concentrations can peak in association with plume passage emanating from an isolated point source. However, the available data suggests that these higher short-term SO_2 levels are localized, within ambient standards, and atypical of the region as a whole. Annual SO_2 concentrations appear to range from only about 5 to 15% of the state and federal standards.

Nitrogen Dioxide

A very limited amount of NO_2 data is available for the ES region because of the small number of monitoring sites in the area. Table R2-31 summarizes the available data. Station A-17 represents rural background concentrations of NO_2 on the outskirts of the town of Kemmerer. The maximum 24-hour concentration is reported as 14 $\mu g/m^3$, and the annual arithmetic mean is reported as 7 $\mu g/m^3$, only 7% of the federal and state primary standard of 100 $\mu g/m^3$.

The other five monitoring stations represent industrial background levels and range from 2 to 24 $\mu g\ NO_2/m^3$. Monitor A-20 was installed directly downwind of the Jim Bridger Power Plant to monitor impact of the plant's emissions. Measurement of NO_2 at the plant site (A-18), and Point of Rocks site (A-19) are thought to be closely related to local and highway traffic patterns, respectively. Diurnal peaks at these latter sites are early morning coincident with increased traffic levels and cold stable air at the surface (Crow and Hadley 1975). However, no violations of the federal NO_2 annual standard were found in southwestern ES region.

Visibility

The data sets used for establishing background visibility are comprised of five years of hourly visual observations taken between sunrise and sunset at both the Fort Bridger (1950 to 1954) and Rock Springs (1960 to 1964) airports.

Visual observations are made of physical objects at known downwind distances. These data sets document discrete ranges in horizontal visibility from zero (< 1/16 mile) to greater than 100 miles (unlimited). Obscurations to horizontal visibility, such as fog, haze, smoke or blowing dust, are manditorily recorded only if visibility is limited to less than seven statute miles during a given hourly period. Table R2-32 presents the number of hours and percent frequency of occurrence of horizontal visibility observations in seven distance ranges for both the Fort Bridger and Rock Springs Airports. As indicated, Fort Bridger and Rock Springs had a total of 21,932 and 21,989 hours of visibility observations during the daylight hours of their respective five-year records.

Prominent topographic features at a distance of 41 to 50 miles from both the Fort Bridger and Rock Springs Airports appear to be easily referenced in visual observations, since about 57% and 67% of all daytime observations were tabulated in that range at each site, respectively. Otherwise visual range was evenly distributed between 11 and 40 miles at Fort Bridger. However, a secondary peak in the frequency of visual

TABLE R2-31

CONCENTRATIONS OF NO_2 IN SOUTHWESTERN WYOMING

($\mu g/m^3$)

Site	Sampling Year	No. Observations	Max. 24-Hr Conc.	2nd Highest 24-Hr Conc.	No. Violations of Federal Annual Std.	Annual Arithmetic Mean
A-17	1976	9	14	12	0	7
A-14	1974-1975	NA	NA	NA	0	<2
	1975-1976	NA	NA	NA	0	2
A-15	1974-1975	NA	NA	NA	0	<2
	1975-1976	NA	NA	NA	0	2
A-18	1974-1975	NA	NA	NA	0	4
	1975-1976	NA	NA	NA	0	4
A-19	1974-1975	NA	NA	NA	0	14
	1975-1976	NA	NA	NA	0	24
A-20	1974-1975	NA	NA	NA	0	4
	1975-1976	NA	NA	NA	0	4

NA means not available.

TABLE R2-32

FIVE-YEAR SUMMARY OF HORIZONTAL VISIBILITY RECORDED
IN THE ES REGION

Horizontal Visibility (miles)	Fort Bridger			Rock Springs		
	Number of Daylight Observations	Differential Frequency (%)	Cumulative Frequency (%)	Number of Daylight Observations	Differential Frequency (%)	Cumulative Frequency (%)
>50	451	2.06	2.06	56	0.26	0.26
41-50	12,490	56.95	59.01	14,639	66.57	66.83
31-40	3,079	14.04	73.05	45	0.20	67.03
21-30	2,828	12.89	85.94	336	1.53	68.56
11-20	1,700	7.75	93.69	5,495	24.99	93.55
6-10	639	2.91	96.60	623	2.83	96.38
≤5	745	3.40	100.00	795	3.62	100.00
TOTAL	21,932	100.00	100.00	21,989	100.00	100.00

observations between 11 and 20 miles was observed at the Rock Springs site. But, the existence of this secondary peak in visual range most likely results from another prominent landmark in the airport observers' line of sight, instead of a discontinuity caused by a real optical phenomenon.

There were no observations of blowing dust or sand that restricted visibility to less than 7 miles at either Fort Bridger or Rock Springs during their respective five-year recording periods. The visibility was restricted by smoke and/or haze during only six and four hours at Fort Bridger and Rock Springs, respectively. In addition, both fog and blowing snow significantly reduced visibility during less than 1% each of the total daylight hours at the two airport sites. Rain and snow, although occurring relatively infrequently, appear to be the mechanisms that limit horizontal visibility most frequently in the ES region.

In summary, visual range in the ES region is good. The coincidence of the modal differential frequencies at the two airport sites is not significant, but that more than one-half of all visual observations at each site exceeds 40 miles suggests that it would be a minimum distance reasonable for the definition of background visual range in southwest Wyoming.

FUTURE ENVIRONMENT WITHOUT THE PROPOSED ACTION

Climate

From a review of the climatological data available, there are no obvious indications that over the next fifteen years the climate of southwestern Wyoming will differ from what exists now. In addition to the proposed coal development activities addressed, other project actions, like the Naughton and Jim Bridger power plant expansions, are scheduled for completion during this time. However, given the data available at the present time, no judicious estimate can be made of the adverse impact, if any, on the regional climate.

Air Quality

An estimate of probable increases in particulate and fugitive dust emissions in the ES region through 1990 is made in Section 4. Subsequently, the baseline TSP monitoring data, in concert with scaling factors derived from these projections, were used to estimate future TSP concentrations. Note that the following data includes population growth associated with the proposed actions. Consequently, the estimate of future air quality does not include the direct impact of the proposed actions alone and is thus somewhat conservative. The lack of resolution in the baseline data (both population and air quality) prevents a more precise distinction between the scenarios addressing indirect air quality impact and future environment without proposed actions.

Each of the proposed mining areas is to be located in a rural setting. In addition, each is displaced either in a favorable upwind position or at a sufficient downwind distance from concentrated industrial activity to have the local air quality described as rural as well. The immediate vicinities of Rock Springs, Green River, or Kemmerer and the trona patch near Little America reflect TSP levels characteristic of their more anthropogenically influenced environments. These areas display a mix of residential, commercial, and industrial influences.

For example, in the vicinity of Rock Springs, TSP levels are expected to increase as a result of increases in local traffic and construction activity. Particulate levels are also expected to increase in the trona patch because of expansion of the Allied Chemical Plant. Available data indicate that the Allied plant will emit 657 tons per year additional particulates after expansion and assuming continuous operation, an

increase of approximately 45% over its 1975 particulate emissions level of 1,432 tons per year. The expansion of the Jim Bridger Power Plant and the proposed expansion of the Naughton Power Plant are expected to increase particulate emissions at maximum load by 325 pounds per hour (~5%) and 262 pounds per hour (~20%), respectively.

Vol 2 p.17 says 25%

Thus, ground-level TSP concentrations should increase in all areas, but not in a homogeneous spatial pattern, as suggested by emissions burden considerations alone. Other factors such as meteorology, source geometry, and topography, all exert external influences of varying degrees on ambient TSP levels. Consequently, a range of baseline TSP concentrations typical of rural, industrial, and urban areas was evaluated. Concentrations of TSP representative of a 24-hour averaging period were based on second highest levels observed during the 1975-1976 baseline period, since the second highest value is appropriate for comparison with the state and federal short-term standard.

Figures R2-9 and R2-10 present a series of bar graphs depicting the approximate ranges of TSP levels (exclusive of the effects from the proposed coal activities) for 1975 through 1990 for annual and 24-hour averaging periods, respectively. The baseline estimates for the different subregions (i.e., rural, industrial and urban) were selected from TSP monitors according to their location and generic specification as shown in Table R2-28. Certain monitors were discounted from consideration since their samples were thought to be dominated by isolated source activities and thus nonrepresentative of the intended subregion. For example, the high volume sampler located at the Jim Bridger Power Plant (Site A-18) was not considered because of the strong influence of construction activity associated with plant expansion. These TSP levels are considered representative of the immediate construction area alone and not characteristic of the ambient air quality the general public is exposed to daily.

Projections of urban (or industrial) impact or background concentrations were made in the following four-step process:

- selecting a representative TSP range for the baseline case;
- separating the estimated contribution of rural background from the urban or industrial contribution;
- scaling the composite parts on an individual basis; and
- recombining the scaled rural background component to the scaled urban or industrial component.

The projected rural background should generally be representative of the ES region except for the few urban and/or industrial areas previously discussed. TSP levels calculated for 1990 are assumed to be

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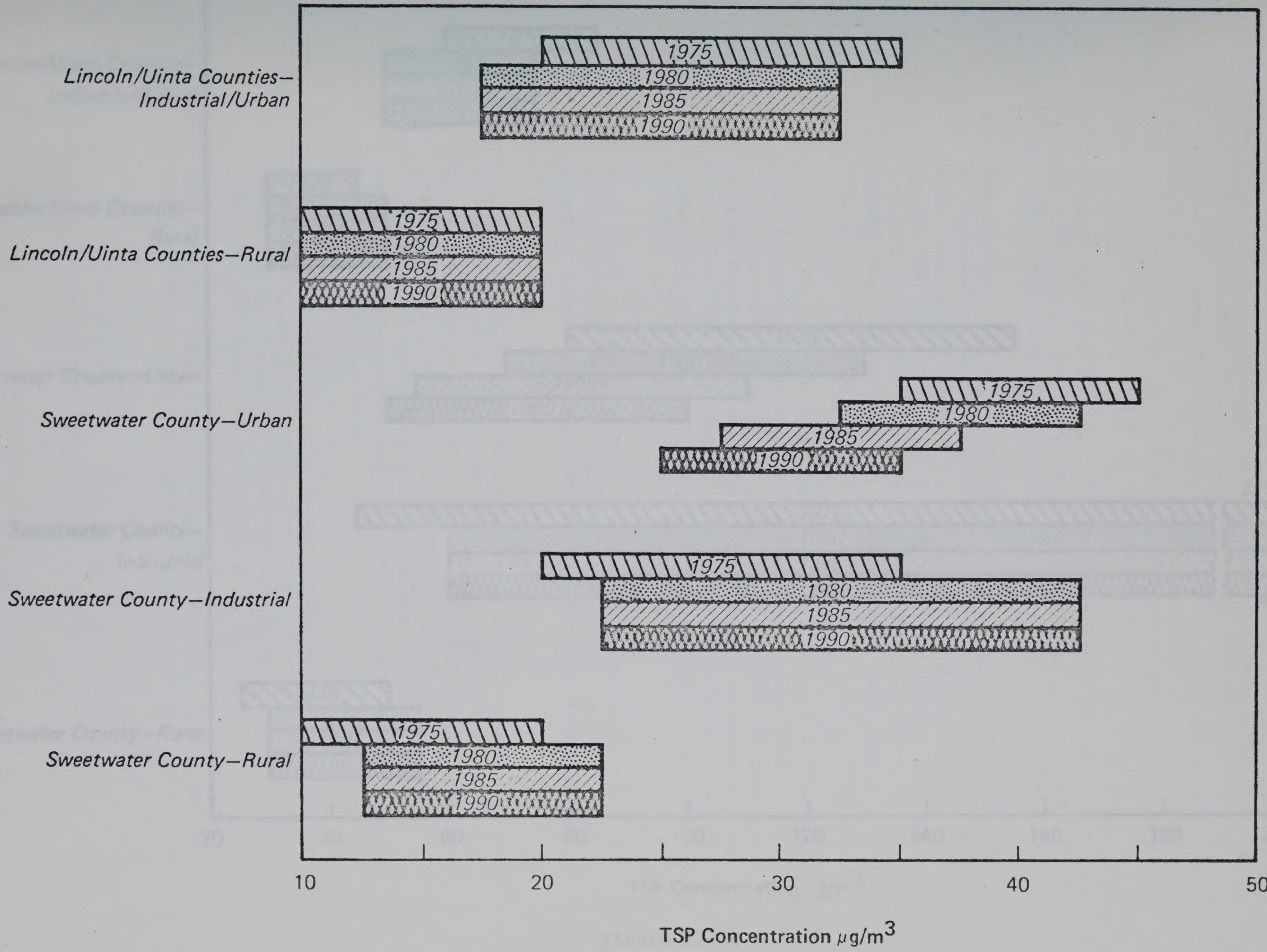

Figure R2-9

Ranges in Annual Background TSP Concentrations in ES Region

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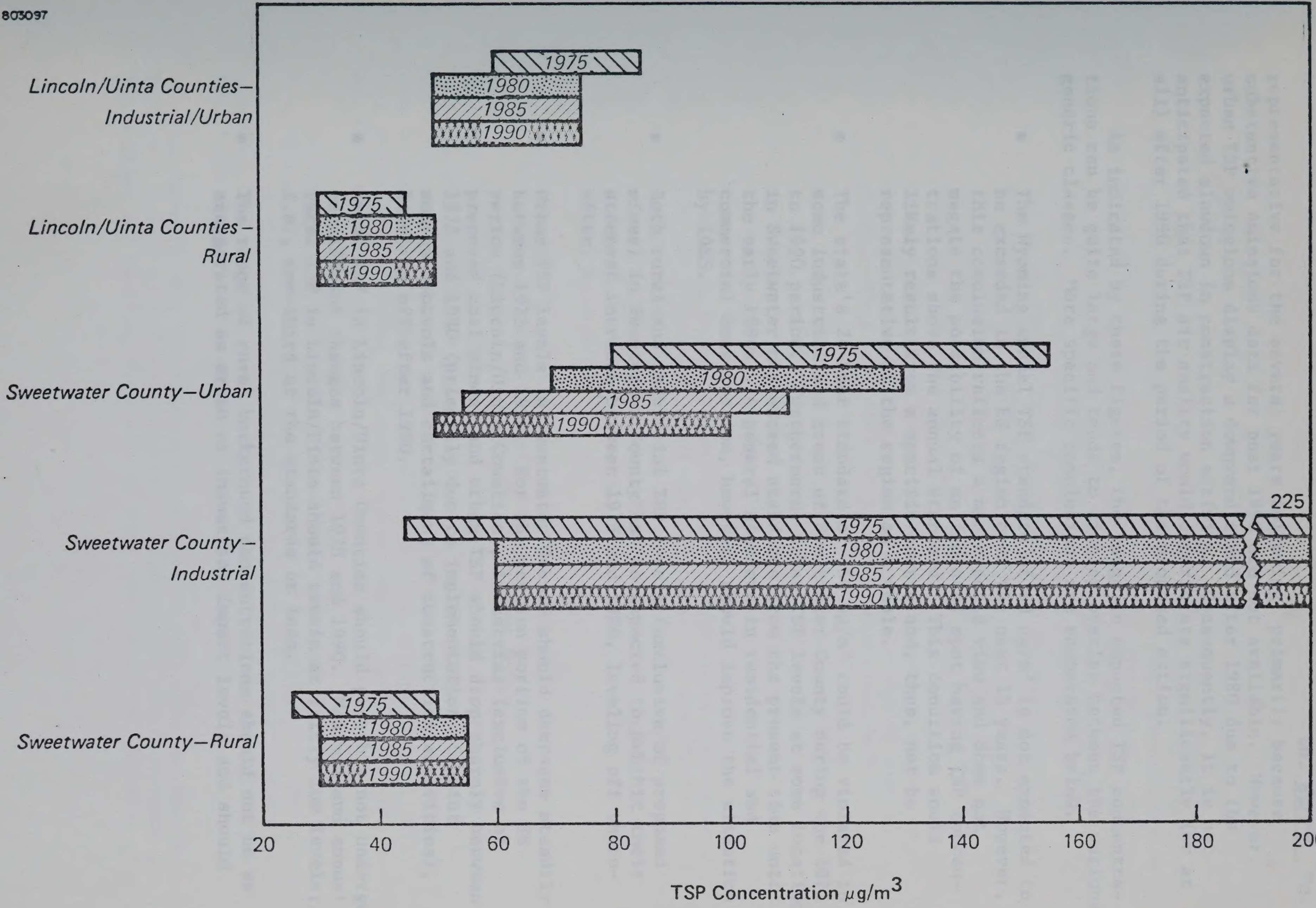

Figure R2-10
Ranges in 24-Hour Background TSP Concentrations in ES Region

representative for the several years following, primarily because substantive emissions data for post 1990 are not available. However, urban TSP emissions display a downward trend after 1980 due to the expected slowdown in construction activity. Consequently, it is not anticipated that TSP air quality would deteriorate significantly (or at all) after 1990 during the period of the proposed action.

As indicated by these figures, the range in expected TSP concentrations can be quite large and tends to display overlap between the various generic classes. More specific conclusions are enumerated below.

- The Wyoming annual TSP standard of 60 $\mu g/m^3$ is not expected to be exceeded in the ES region over the next 15 years. However, this conclusion reflects a macro-scale view and does not negate the possibility of an isolated spot having TSP concentrations above the annual standard. This condition would likely result from a specific source and, thus, not be representative of the region as a whole.
- The state's 24-hour standard of 150 $\mu g/m^3$ could be violated in some industrialized areas of Sweetwater County during the 1975 to 1990 period. Furthermore, urban TSP levels at some locations in Sweetwater may exceed standards from the present time until the early 1980s. A general slowdown in residential and commercial construction, however, should improve the situation by 1985.
- Both rural and industrial TSP levels (exclusive of proposed mines) in Sweetwater County can be expected to exhibit their steepest increase between 1975 and 1980, leveling off thereafter.
- Urban TSP levels in Sweetwater County should decrease steadily between 1975 and 1990. For the western portion of the ES region (Lincoln/Uinta Counties), industrial (exclusive of proposed coal mines) and urban TSP should drop sharply between 1975 and 1980 (primarily due to implementation of point source controls and curtailment of construction activities), leveling off after 1980.
- Rural TSP in Lincoln/Uinta Counties should probably not undergo significant changes between 1975 and 1990. Maximum and annual rural TSP in Lincoln/Uinta should remain at fairly low levels; i.e., one-third of the standards or less.
- The range of rural background concentrations should not be as exaggerated as urban or industrial impact levels and should

primarily reflect differences in site exposure, local soil conditions, or plant cover, which in turn regulate the naturally induced emissions of fine particles into the atmosphere. For conservatism, however, growth rates of rural background TSP are based on the aggregate of all anthropogenic emissions of particulates within the subregion of interest (Sweetwater or Lincoln/Uinta Counties). Therefore, if the natural component of rural background TSP is assumed to remain relatively constant from year to year, future projected concentrations for rural areas would be overestimated. However, the maximum error (the degree of overprediction) attributable to anthropogenic scaling is about one-third (see Figure R2-10, Lincoln/Uinta Counties) the range of rural concentrations for the 24-hour TSP and about 25% (Figure R2-9, Sweetwater County) of the range of rural concentrations for the annual TSP.

- Maximum and annual industrial (exclusive of new mines) or urban TSP levels in the western portion of the ES region should remain below 50% of the appropriate standard.

- Wide ranges of current and projected urban and industrial TSP levels are possible, although the ranges estimated in Figures R2-9 and R2-10 are more a function of the local influences on a limited number of sampling stations than future growth projections. The range is especially broad for Sweetwater County industrial areas: about 25 $\mu g/m^3$ (over 40% of the standard) for the annual range and about equal to the standard (160 $\mu g/m^3$) for the 24-hour range. Because the two most heavily industrialized areas of the county are so widely separated in geography and in type of activity, a range of this magnitude may not be wholly unrealistic.

Increases in SO_2 emissions are expected with the expansion of Jim Bridger Power Plant and the proposed expansion of Naughton Power Plant. In 1975, the Jim Bridger plant emitted a total of 15,000 pounds SO_2 per hour for three units. Unit 4 will be added in 1978 and will contribute 1,000 pounds per hour to the SO_2 emissions level (7% increase). All units will be operational by 1980. Concurrently, with the addition of Unit 4, Units 1, 2, and 3 will be retrofitted with scrubbers by 1985, thus reducing the overall SO_2 emissions of the four units to only 34% of the 1975 level.

In 1975, the Naughton Power Plant emitted 21,689 tons SO_2 per year from three units. Utah Power & Light plans to construct two additional units at the Naughton plant that will each emit 547 pounds per hour, assuming a 90% scrubber efficiency. Thus, the increase in SO_2 emissions from Units 4 and 5 will only be 5% over 1975 levels.

Increases in NO_x emissions are anticipated near Rock Springs and I-80 as a result of increased traffic. In addition, the expansions at Jim Bridger and Naughton Power Plants will contribute to slightly

increased NO_x emissions. At Jim Bridger Power Plant, NO_x emissions will increase 3,514 pounds per hour, or 25% about the Units 1 to 3 as a result of adding Unit 4. At the Naughton Power Plant, NO_x emissions will increase 7,280 pounds per hour, or about 50% as a result of adding Units 4 and 5.

Visibility

As discussed in "Existing Ambient Air Quality," the average visual range should be about 40 to 50 miles in the ES region without the advent of the proposed coal development actions.

AIR QUALITY IMPACTS

Methods for Evaluating Emissions Inventory

Development of the proposed actions will affect air quality in southwest Wyoming. Specifically, existing pollutant concentrations, such as total suspended particulates (TSP), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), hydrocarbons (HC), and carbon monoxide (CO), will be affected. Coal mining, in general, is a significant source of particulate emissions, and its impact on SO_2, NO_2, HC and CO is relatively small.

An emissions inventory was completed to quantify the sources of particulate emissions within the ES region. Where appropriate, all the conventional source categories detailed in APTD-1135 (EPA 1973a) were included, with the addition of some oil sump burning and fugitive dust categories. Since the most recent, complete, and representative air quality monitoring data characterizing the ES region were measured in 1975, it was chosen as the base year for the emissions inventory. However, state fuel consumption data were available for 1974, but not 1975. Since the magnitude of particulate emissions from fuel consumption is relatively small in comparison to other sources of particulates and since the fuel consumption in this area is not expected to show a significant increase from 1974 to 1975, these data are considered representative of 1975 fuel consumption.

The source categories and their respective calculated emissions are listed in Table R4-1. As indicated by these data, the most significant sources of particulates in the western portion of Sweetwater County* are unpaved roads (52%), construction (23%), and industrial process point sources (8%). In Lincoln County, the most significant particulate emissions* are from industrial processes point sources (47%), unpaved roads (26%), agriculture (12%), and existing coal mines (9%). The most significant particulate sources in Uinta County* are unpaved roads (72%), agriculture (13%), and dust from paved roads (8%).

The following portions of this section present the emissions inventory by source category.

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*Excluding the contribution of railroad haulage and open burning, because there was no breakdown by county for these data.

TABLE R4-1

1975 PARTICULATE EMISSIONS

(tons per year)

	Sweetwater (west)*	Lincoln	Uinta	Combined
Bituminous Coal	7	96	5	
Distillate Oil	39	24	9	
Residual Oil	40	31	12	
Natural Gas	24	12	5	
Wood	2	3	-	
LPG	4	1	1	
Vehicular Sources on Roadways	409	94	118	
Off-Highway Vehicles	11	13	9	
Unpaved Roads	27,783	9,208	7,404	
Dust from Paved Roads	3,043	667	841	
Railroads				339
Aircraft	**	**	**	
Industrial Processes				
Area	38	5	5	
Point	4,255	16,774	70	
Existing Mining	2,106	3,144		
Agriculture	456	4,317	1,291	
Construction	12,275	489	486	
Open Burning	-	-	-	1.4
Aggregate Storage	2,401	733	55	
TOTAL	52,893	35,611	10,311	109,142

*The portion of Sweetwater within the ES region.

**Negligible.

Bituminous Coal Consumption

This section describes the procedure used to determine area source coal consumption and associated particulate emissions of residential, commercial-institutional, and industrial users. Fuel consumption was determined by (1) degree day heating method for residential users, (2) statistics for fuel distribution by county, and (3) apportioning state total usage figures by population.

Residential. The degree day heating method was used to determine residential fuel consumption (EPA 1973a). This method can be described by the equation:

$$A = B \text{ X } C \text{ X } D \text{ X } E \qquad \text{(R4-1)}$$

where

A is the residential fuel consumption

B is the number of occupied dwelling units burning applicable fuel

C is the number of heating degree days in 1974

D is the heating requirement factor for applicable fuel

E is the correction factor for number of rooms per dwelling unit

Table R4-2 indicates the number of dwelling units and annual heating degree days used to calculate residential coal consumption.

The number of dwelling units in 1974 was determined by applying the approximate change in residential coal sales to the 1970 census figures. Coal sales to residential coal users in the state and in Lincoln County were estimated by distributors to be unchanged between 1970 and 1974 and down by 25% in Sweetwater and Uinta Counties (Tyndall 1976; Marvel 1976; Watt 1976).

Other parameters used in the heating degree day equation were taken from published data. The heating requirement factor for bituminous coal is 0.0012 tons of coal per dwelling unit per degree day (EPA 1973a). Heating degree days for Lincoln County were determined by averaging heating degree day calculations at Afton, Border, and Kemmerer. Data representative of Sweetwater County were determined by averaging calculations at Farson, Green River, and Rock Springs. Data representative of Uinta County were determined by calculating heating degree days at Evanston. State statistics were determined by averaging heating degree totals from one observation site in each county (24 sites) (U.S. Dept. of Commerce 1974).

TABLE R4-2

CALCULATED RESIDENTIAL COAL CONSUMPTION

	State	Lincoln	Sweetwater	Uinta
Number of dwelling units burning coal 1970*	3,524	880	107	61
Number of dwelling units burning coal 1974	3,524	880	80	46
Average number of rooms per dwelling unit*	4.7	4.9	4.4	4.8
1974 total heating degree days†	8,012	9,319	8,467	8,758
1974 residential coal consumption (tons)	31,848	9,644	715	464

*U.S. Dept. of Commerce 1970

†U.S. Dept. of Commerce 1974a, 1975

Estimates of 1974 coal sales by county to residential users are as follows:

Lincoln - 5,000 tons (Frontier 1976)
Sweetwater and Uinta - 1,530 tons (Sweetwater 1976)

A comparison of the calculations of fuel usage with distributor sales figures indicates that the calculated values are higher for Lincoln County, but slightly lower for Sweetwater and Uinta Counties.

Since the distribution figures to residential consumers in the three county areas were not always exact, but rather involved approximations of the portion of the total coal sales to all customers, and since the distributor's figures do not necessarily represent coal sales to all residential users in the three-county area, the calculated fuel-use values were used to determine particulate emissions.

Commercial-Institutional. Since the 1974 calculated state residential coal consumption figure, 31,848 tons, is higher than the 1974 state retail dealers sales figure, 24,000 tons (U. S. Department of the Interior 1975a), the assumption was made that the commercial-institutional area source coal consumption is negligible.

Industrial. Industrial coal users were included in the inventory as point sources. There was no evidence of any industrial coal consumers that did not emit a sufficient quantity of pollutants for classification as a point source (25 tons per year) (Wyoming DEQ 1976).

Total Area Source Particulate Emissions from Coal Consumption. The EPA-recommended particulate emission factor for hand-fired units was used (EPA 1973b), since nearly all area source consumption is residential. Applying this factor, 20 pounds of particulates per ton, to the previously determined coal consumption figures yields the following annual particulate emissions (tons per year) by county:

Lincoln	Sweetwater	Sweetwater (west)	Uinta
96	7	6.8	5

Sweetwater County was divided into two separate regions along the boundary that separates the southcentral from the southwestern Wyoming ES region. Most of the county population as well as nearly all of the mining, construction, and industrial activity is located in the western region. Particulate emission ratio factors for the two regions were determined by (1) subtracting the population of the Rock Springs and Green River urban areas from the total population of Sweetwater county, (2) apportioning the remainder of the county population by land area,

(3) adding the Rock Springs and Green River urban area populations to the population of the apportioned western region, and (4) taking the ratio of the population of each region to the total county population. The resulting factors were 0.97 for the western area and 0.03 for the eastern area. The particulate emissions for the western region of Sweetwater county from the burning of bituminous coal are calculated to 6.8 tons per year.

Distillate Oil

Distillate oil usage in 1974 by area sources was determined by (1) contacting major oil distributors who service the area, (2) using the heating degree day method for residential users, and (3) breaking down the state distillate oil consumption totals by population.

Residential. The heating degree day method (see "Bituminous Coal Consumption") was used to determine distillate oil consumption by residential users. The method assumes 0.18 gallons of oil burned per dwelling unit for each degree day (EPA 1973a). The number of dwelling units that burned distillate oil in 1970 was projected to 1974 using distributors' estimates of a 10% growth in residential sales (Delgado 1976) (see Table R4-3). The figure was assumed to approximate the growth in residential sales throughout the state. In Uinta County, the number of residential units that burn distillate oil was estimated from distributors' residential sales, since a multiplicative growth factor cannot change a zero value (Delgado 1976; Brunning 1976).

Major distributors' sales figures for 1974 (in gallons) were estimated to be:

	Lincoln	Sweetwater	Uinta
Residential users	240,000	10,000	1,800
Total sales	800,000*	6,760,000*†Δ	18,000*†

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*Delgado 1976

†Brunning 1976

ΔWest 1976

TABLE R4-3

CALCULATED RESIDENTIAL FUEL CONSUMPTION

(gallons per year)

	State	Lincoln	Sweetwater	Uinta
1970 dwelling units using distillate oil*	6,572	417	23	0
1974 dwelling units using distillate oil	3,929	459	26	2
1974 residential distillate oil consumption	5,326,272	754,537	34,870	3,027

*U.S. Dept. of Commerce 1970

Comparing the calculated oil consumption for all counties with the major distributors' sales to residential users indicates that the calculated total is higher than the sales figures. Since figures from all distributors who service the area were not obtained, the calculated values were used to determine particulate emissions from residential users.

Commercial-Institutional. Commercial-institutional consumption was calculated by apportioning the state distillate commercial consumption statistics by population. State residential and commercial distillate oil consumption (Table R4-4) was taken from 1974 published data (U. S. Department of the Interior 1975b).

The state total was apportioned as follows:

	State	Lincoln	Sweetwater	Uinta
1974 population[§]	359,000	9,300	25,900	7,700
Apportionment factor (county/state population)	-	0.026	0.072	0.021
1974 commercial-institutional distillate oil consumption (10^3 gallons)	-	970	2,686	783

Industrial. State industrial distillate oil consumption figures were apportioned to the counties on the basis of the number of mining, contract construction, and manufacturing employees (Wyoming Industrial Development Commission 1975; Ogara 1976). The fuel usage figures (10^3 gallon) were taken from 1975 published data (U.S. Department of Commerce 1974b):

State industrial oil sales	19,236 (458,000 barrels)
State oil company sales	16,338 (389,000 barrels)
1974 state point and area source industrial distillate oil consumption	35,574

The Table R4-5 indicates the apportionment of the state fuel sale figures by county.

[§] U.S. Dept. of Commerce 1974b

TABLE R4-4

COMMERCIAL AND INSTITUTIONAL FUEL OIL CONSUMPTION

(10^3 gallons)

1974 state distillate ("other") consumption	37,842 (901,000 barrels)
1974 distillate used by military	420 (10,000 barrels)
1974 state kerosene used for heating	4,704 (112,000 barrels)
1974 state residential and commercial-institutional distillate oil consumption	42,966
Less 1974 state residential distillate oil consumption	(5,666)
1974 state commercial-institutional distillate oil consumption	37,300

TABLE R4-5

STATE INDUSTRIAL FUEL OIL SALES BY COUNTY

	State	Lincoln	Sweetwater	Uinta
1974 mining, construction, and manufacturing employees	38,600	1,654	8,913	433
Apportionment factor (county/state employees)	-	0.043	0.231	0.011
1974 distillate point and area source totals (10^3 gallons)	-	1,530	8,218	391
Less 1974 point source industrial distillate oil consumption (10^3 gallons)*	-	0	(5,604)	0
1974 area source industrial distillate oil consumption (10^3 gallons)	-	1,530	2,614	391

*Wyoming DEQ 1976; PEDCo 1975

Total Residential, Commercial-Institutional, and Industrial Area Source Distillate Fuel Usage. Comparison of calculated fuel totals with distributors' total fuel sales figures indicates that with the exception of Sweetwater County, the calculated figures are higher. Since the distributors' figures are often estimates and do not always account for total distillate fuel sales in the three-county area, the calculated values were used to determine particulate emission totals.

Total 1974 area source distillate fuel consumption (gallons) by county follows:

Lincoln	Sweetwater	Uinta
3,255,000	5,335,000	1,177,000

Total Area Source Particulate Emissions from Distillate Oil Consumption. The emission factor for distillate fuel is 15 pounds per 1,000 gallons (EPA 1973b). The application of the factor yields the following particulate totals (tons per year) by county:

Lincoln	Sweetwater (west)*	Uinta
24	39	9

Residual Oil

Residual oil consumption was determined by apportioning state residual oil sales totals by population. The assumption was made that there is no residential usage of residual oil in the three-county area, since this fuel is too viscous for residential use. Only commercial-institutional and industrial totals were calculated.

Commercial-Institutional. State commercial-institutional residual oil sales figures were apportioned to the counties on the basis of relative population density. There was no evidence to indicate residual fuel consumption by commercial-institutional point sources (Russell 1976; Collins 1976). Residual oil sales for 1974 to commercial-institutional users total 22,134 (10^3 gallons) (U.S. Department of the Interior 1975b).

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*Apportioned to represent western section of Sweetwater County. See "Bituminous Coal Consumption."

The state figure for total commercial-institutional residual fuel usage (10^3 gallon) was apportioned to the counties by population (see "Distillate Oil").

State	Lincoln	Sweetwater	Unita
22,134	575	1,594	465

Industrial. Industrial residual oil consumption for the three-county area was calculated by multiplying the state total industrial residual oil consumption by the ratio of the number of mining, manufacturing, and contract construction employees in each of the three counties to the number of these employees in the state (see "Distillate Oil"). The following indicates the point and area source state industrial residual oil consumption (10^3 gallon) as determined from 1975 published data (U. S. Department of the Interior 1975b).

State industrial sales of residual oil	12,096 (288,000 barrels)
State residual oil company sales	36,582 (871,000 barrels)
1974 state total residual oil sales to industrial point and area sources	48,678

Table 4-6 indicates the apportionment of the state industrial residual fuel usage by county.

Total Residential, Commercial-Institutional, and Industrial Area Source Residual Fuel Usage. The total 1974 area source residual oil consumption (10^3 gallon) by county is:

Lincoln	Sweetwater	Uinta
2,668	3,551	1,000

Total Area Source Particulate Emissions From Residual Oil Consumption. The emission factor for residual oil consumption is 23 pounds of particulates per 1,000 gallons of fuel burned (EPA 1973b). The calculated total area source particulate emissions (tons per year by county) are:

Lincoln	Sweetwater (west)*	Uinta
31	40	12

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*Apportioned to represent the western section of Sweetwater County. See "Bituminous Coal Consumption."

TABLE R4-6

STATE INDUSTRIAL RESIDUAL OIL CONSUMPTION

(10^3 gallons)

	State	Lincoln	Sweetwater	Uinta
1974 point and area source industrial residual	48,678	2,093	11,245	535
Less 1974 point source industrial residual	-	0*	(9,048)**	0
1974 industrial area source residual	-	2,093	1,957	535

*Russell 1976; Collins 1976.

**PEDCo 1975.

Natural Gas

This section describes the procedures used to determine area source natural gas consumption and associated particulate emissions of residential, commercial-institutional, and industrial users.

Residential. Residential usage of natural gas was calculated by apportioning state natural gas sales on the basis of number of dwelling units using natural gas. During the 1970 to 1974, the number of residential consumers of natural gas increased by approximately 21% in the state, while the sales volume decreased (U. S. Department of the Interior 1975c). Communication with a major natural gas distributor indicated a similar pattern in the three-county area (Peterson 1976). Since 1974 distribution figures were not obtained from all distributors who serviced the area, the percentage increase in the number of state residential users was applied to the calculated 1970 statistics for the three-county area (see Table R4-7).

Commercial-Institutional. Commercial-institutional consumption in the counties was determined by apportioning state sales figures (U. S. Department of the Interior 1975c) on the basis of population (U. S. Department of Commerce 1974b). There was no evidence of consumption of natural gas by commercial-institutional users large enough to designate them as point sources (25 tons of pollutant per year) (Russell 1976; Collins 1976).

	State	Lincoln	Sweetwater	Uinta
1974 population	359,000	9,300	25,900	7,700
Commercial-institutional area source usage (MMCF)	13,241	344	953	278

Industrial. Industrial area source emissions for the ES region were determined by apportioning state industrial fuel usage figures (see Table R4-8) on the basis of number of mining, manufacturing, and construction employees (see "Bituminous Coal Consumption").

Total Residential, Commercial-Institutional, and Industrial Area Source Natural Gas Fuel Usage. The following is the total 1974 natural gas area source consumption (MMCF) by county:

Lincoln	Sweetwater	Unita
2,464	5,020	1,050

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TABLE R4-7

CALCULATED NATURAL GAS USAGE

	State	Lincoln	Sweetwater	Uinta
1970 dwelling units using natural gas*	80,524	550	5,520	1,679
1974 dwelling units using natural gas†	98,000**	669††	6,718††	2,043
1974 natural gas consumption by residential users [Millions of cubic feet (MMCF)]	12,064†	82	822	251

* U.S. Dept. of Interior 1970.

** U.S. Dept. of Interior 1975.

† U.S. Dept. of Interior 1975c.

†† Projection based on the ratio of state sales figures (1974 to 1970).

TABLE R4-8

INDUSTRIAL CONSUMPTION OF NATURAL GAS
(MMCF)

	State	Lincoln	Sweetwater	Uinta
1974 industrial fuel usage	47,398	2,038	10,949	521
Less 1974 point source usage	-	-	7,704	-
Total 1974 industrial area source fuel usage	-	2,038	3,245	521

Total Area Source Particulate Emissions. The particulate emission factor for the burning of natural gas is pounds per MMCF (EPA 1973b). The following indicates the total area source particulate emissions (tons per year by county) from burning natural gas:

Lincoln	Sweetwater (west)*	Uinta
12	24	5

Other Fuels

In addition to the major fuels previously discussed, wood and liquefied petroleum gas (LPG) are also burned. The consumption of each type of fuel was determined as follows.

Wood. Residential wood consumption was determined using the degree day heating method (see "Bituminous Coal Consumption"). The heating requirement factor for tons of wood burned per dwelling unit per degree day is 0.0017 (EPA 1973a). The estimated total wood consumption by county in 1974 is shown in Table R4-9.

Since there was no evidence to indicate wood consumption by commercial-institutional or industrial sources that were not designated point sources, the commercial-institutional and industrial area source wood consumption was assumed to be negligible.

Liquefied Petroleum Gas. The 1974 state fuel-usage figures indicate a combined commercial-institutional and residential consumption of 45,164,000 gallons (U. S. Department of the Interior 1975d). This combined consumption was separated using the ratio of residential to commercial-institutional consumption for natural gas (U. S. Department of the Interior 1975c) of 12,064/13,241. Therefore, the estimated 1974 residential LPG consumption is approximately 21,543,000 gallons, and the 1974 commercial LPG consumption is approximately 23,620,000 gallons.

Residential. Residential LPG consumption for each county was determined by apportioning the state LPG total figure (U. S. Department of the Interior 1975d) by the number of dwelling units using LPG (U. S.

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*Apportioned to represent western section of Sweetwater County. See "Bituminous Coal Consumption."

TABLE R4-9

1974 ESTIMATED TOTAL WOOD CONSUMPTION BY COUNTY

	Lincoln	Sweetwater	Uinta
1970 dwelling units using wood	42	25	0
1974 dwelling units using wood (assumed unchanged since 1970)	42	25	0
1974 residential wood consumption (tons)	652	317	0

*U.S. Dept. of Commerce 1970

Department of Commerce 1970). The change in LPG usage from 1970 to 1974 was estimated by a major LPG distributor in the area (Hebert 1976). State LPG sales were expected to increase in proportion to state population increases.

	State	Lincoln	Sweetwater	Uinta
1970 dwelling units using LPG	13,474	534	294	164
Growth factor	1.08	0.59	2.17	2.21
1974 dwelling units using LPG	14,552	315	638	362
1974 residential LPG consumption (10^3 gallons per year)	21,543	466	945	536

Commercial-Institutional. Commercial-institutional LPG consumption was calculated by apportioning the 1974 state commercial-institutional LPG consumption (10^3 gallon) (U. S. Department of the Interior 1975d) by population (see "Distillate Oil").

State	Lincoln	Sweetwater	Uinta
23,620	614	1,700	496

Industrial. Industrial LPG consumption was calculated by apportioning the 1974 state industrial LPG usage (10^3 gallon) (U. S. Department of the Interior 1975d) by the number of mining, contract construction, and manufacturing employees (see "Distillate Oil").

State	Lincoln	Sweetwater	Uinta
5,505	237	1,272	61

Residential, Commercial-Institutional, and Industrial Total Area Source LPG Usage. The total LPG consumption (10^3 gallon) by county in 1974 is:

Lincoln	Sweetwater	Uinta
1,317	3,917	1,093

Total Area Source Particulate Emissions. The emission factors used to determine particulate emissions were 10 pounds per ton for wood and 1.9 pounds per 10^3 gallon for LPG (EPA 1973b). Applying these factors to the wood and LPG usage figures results in the following calculated

particulate emission (tons per year) by county:

	Lincoln	Sweetwater (west)*	Uinta
Wood	3	2	0
LPG	1	4	1

Vehicular Sources

Vehicular Exhaust, Tire Wear, and Brake Wear. The emission factors associated with these three categories were promulgated by the EPA (1975). These factors are presented in Table R4-10.

For this analysis, it was assumed that LDD and LDGT have four wheels, HDGT has six wheels, and HDD has fourteen wheels. Data obtained from the Wyoming State Highway Department (WSHD) indicated that the Wyoming vehicle mix operating on paved roads consisted of 65.1% LDV, 28.3% LDGT, 5.6% HDGT, and 1% HDD (Garrett 1976). Additionally, the vehicle mix on unpaved roads consisted of LDV and LDGT only (Garrett 1976). It was assumed that these statistics represented the 1975 vehicle mix operating in the ES region. The WSHD also provided data on the average daily vehicle miles traveled (VMT) by road type. The data compiled for annual VMT included three categories: (1) data reported for road codes 01, 02, 31, 32, 03, 04, 05, and 06 (WSHD 1976), (2) data reported for all other paved roads (Garrett 1976), and (3) data obtained for unpaved roads (Garrett 1976). These data are presented in Table R4-11.

The data in Table R4-11 were multiplied by the appropriate emission factors, by vehicle type, weighed by their percentage of the vehicle population, to obtain the 1975 emissions from exhaust, tire, and brake wear (tons per year):

County	Emissions
Lincoln	94
Sweetwater (west)*	409
Uinta	118

To determine the particulate emissions from off-highway vehicular sources, fuel consumption was calculated for each county. The calculated fuel consumptions were multiplied by the appropriate emission factors, obtained from AP-42 (EPA 1975) to determine the particulate emissions generated by these sources (tons per year):

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*Apportioned to represent the western section of Sweetwater County. See "Bituminous Coal Consumption."

TABLE R4-10

PARTICULATE EMISSION FACTORS

(grams per vehicle mile)

	Light Duty Vehicle (LDV)	Light Duty Diesel (LDD)	Light Duty Gas Truck (LDGT)	Heavy Duty Gas Truck (HDGT)	Heavy Duty Diesel (HDD)
Exhaust	0.34	0.73	0.34	0.91	1.3
Tire wear*	0.20	a	0.20T	0.20T	0.20T
Brake wear	0.13	b	c	c	c

Note:

T represents the number of tires divided by four

a was assumed to be 0.20

b was assumed to be 0.13

c was assumed to be 0.13T

*Due to limited tire wear data, these factors were chosen to represent vehicles operating on either paved or unpaved roads.

TABLE R4-11

ANNUAL VEHICLE MILES TRAVELED

County	Road Type	VMT
Lincoln	Code 01-06, 31, 32	100,377,190
	Other*	13,968,404
	Unpaved	2,972,341
Sweetwater	Code 01-06, 31, 32	427,335,065
	Other*	89,525,558
	Unpaved	9,089,705
Uinta	Code 01-06, 31, 32	127,780,660
	Other*	16,410,035
	Unpaved	2,414,037

*Includes bituminous, cement, and oil penetration surfaces.

County	Emissions
Lincoln	13.
Sweetwater (west)*	11.1
Uinta	9

Dust From Unpaved Roads. Vehicle movements along unpaved roads generate particulate emissions by disturbing the road surface. The emissions associated with these movements were calculated by the following equation:

$$E = VMT \; 0.6 \; (0.81 \; s) \; \frac{S}{30} \left(\frac{365 - W}{365} \right) \; \dagger \qquad \text{(R4-2)}$$

where

E	is the emissions pounds per day
VMT	is the daily vehicle miles traveled
0.6	accounts for the particles whose size is ≤ 30 μm (EPA 1973b)
0.81	is an EPA constant
s	is the percent silt content of road
S	is the average vehicle speed
$\frac{365 - W}{365}$	accounts for the days when there was greater than 0.1 inches of rain and/or snow cover

The WSHD provided data regarding the miles of unpaved roads, surface type, average daily traffic, and average vehicle speed in each county (Garrett 1976) (see Table R4-12). The State Soil Scientist and BLM Soil Scientist provided data on average silt content (Fowkes 1976; Crane 1976). The results of these calculated 1975 particulate emissions from vehicular movements on unpaved roads (tons per year) are:

County	Emissions
Lincoln	10,645
Sweetwater (west)**	32,231
Uinta	8,560

---

*The total emissions in Sweetwater County were apportioned by the ratio detailed in "Bituminous Coal Consumption."

**Apportioned to represent the western portion of Sweetwater County. See "Bituminous Coal Consumption."

†This formula was promulgated by the EPA (1975).

TABLE R4-12

INPUTS TO CALCULATIONS FOR UNPAVED ROAD EMISSIONS

County	Length (miles)	ADT	Speed (mph)	Silt Content	$\left(\frac{365 - W}{365}\right)$
Lincoln					
City Roads					
Bladed	-	10	35	30*	0.58
Graded and drained	0.08	30	35	30	0.58
Gravel	7.83	50	35	12**	0.58
All Other					
Bladed	53.9	5	35	30	0.58
Graded and drained	282.92	10	35	30	0.58
Gravel	232.54	20	35	12	0.58
Sweetwater					
City Roads					
Bladed	4.31	10	35	30	0.69
Graded and drained	11.56	30	35	30	0.69
Gravel	13.28	50	35	12	0.69
All Other					
Bladed	316.00	5	35	30	0.69
Graded and drained	372.72	10	35	30	0.69
Gravel	927.11	20	35	12	0.69
Uinta					
City Roads					
Bladed	0.08	10	35	30	0.58
Graded and drained	2.01	30	35	30	0.58
Gravel	9.46	50	35	12	0.58
All Other					
Bladed	73.3	5	35	30	0.58
Graded and drained	202.26	10	35	30	0.58
Gravel	184.53	20	35	12	0.58

*Fowkes and Crane 1976

**EPA 1973b

Dust from Paved Roads. Little information exists regarding the particulate emissions generated by vehicle movements on paved roads. For this study, emission factors developed for the Seattle area (Roberts et al. 1972) are considered applicable to Wyoming. The emissions calculation used was:

$$E = \frac{(F-20)(1.75) + (20)(77)}{365} \qquad \text{(R4-3)}$$

where

E is the emissions (grams per VMT)

F is the 365 - W

The VMT statistics were supplied by the WSHD and are presented in Table R4-13.

These data were multiplied by the appropriate emission factors to obtain the emissions from dust from paved roads (tons per year):

County	Emissions
Lincoln	141
Sweetwater (west)*	740
Uinta	178

Railroads

Within the region of interest, the Union Pacific operates the most significant portion of railroad movements. The following data were obtained from Union Pacific (Catalan 1976):

1. For 1975, assume that 2.191 gallons of fuel were used per 1,000 gross tons per moving mile.

2.

Railroad Segment	1975 Haulage (billion gross ton miles)
Rawlins to Green River	8.9
Green River to Utah	4.6
Green River to Idaho	3
Branches (Collective)**	0.018

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*Apportioned to represent the eastern section of Sweetwater County. See "Bituminous Coal Consumption."

**Assumes this haulage is between Rock Springs and Winton Junction (Catalan 1976).

TABLE R4-13

1975 ANNUAL VEHICLE MILES TRAVELED

County	Road Type	VMT
Lincoln	Code 01-06, 31, 32	100,377,190
	Bituminous and cement surface	13,755,554
Sweetwater	Code 01-06, 31, 32	427,335,065
	Bituminous and cement surface	89,280,369
Uinta	Code 01-06, 31, 32	127,780,660
	Bituminous and cement surface	16,290,589

3. Rawlins to Table Rock 63.9 miles of track

Rawlins to Green River 134.2 miles of track

Assume haulage between Table Rock and Green River is proportional to the length of track between these two points. Therefore, the 1975 haulage between Table Rock and Green River was 4.7 billion gross tons.

Based on these data, the fuel consumed by railroad movements in all three counties in 1975 was 27,124,580 gallons per year. To calculate particulate emissions from railroad fuel consumption, the EPA emission factor of 25 pounds per 10^3 gallon (EPA 1973b) was used. The calculated 1975 particulate emissions from railroad fuel consumption are 339 tons per year.

Aircraft

Aircraft operations within the ES region are limited. As indicated by Table R4-14, the most significant operations occur in Rock Springs. A previous study performed for the Wyoming DEQ (PEDCo 1975) included an analysis of the particulate emissions generated by aircraft operations (landing and takeoff) in Rock Springs. In this analysis, the impact of a total of 40,000 landing and takeoff cycles of various aircrafts had been analyzed. The analysis had indicated that the cumulative effect of these operations resulted in 3.6 tons per year TSP emissions. This value is not even 1% of the emissions from unpaved roads.

Due to the low aircraft volumes and limited data concerning aircraft type and operations, the analysis of particulate emissions from aircraft operations was not performed for this study.

Industrial Processes

Area Sources. Due to the numerous, highly dispersed source locations and rather low emission rates, only two industrial processes were included in the area source emissions inventory. These processes were heater treater operations for removing water from crude petroleum and gas compression operations for pipeline transmission of natural gas.

Information concerning the number and approximate location of heater treaters was obtained from several sources (Malhalland 1976; Brookshire 1976). Virtually all heater treaters operate by combustion of natural gas (PEDCo 1975). It was assumed that there was one heater treater per active petroleum lease. Other assumptions regarding average

TABLE R4-14

AIRPORT ACTIVITY*

County/Airport	Operations per Year
Sweetwater	
Rock Springs	26,060
Webster Air Strip	**
Lincoln	
Afton	2,065
Alpine	**
Cokeville	700
Kemmerer	
Uinta	
Evanston	7,410
Fort Bridger	450

*Data obtained from Krauser 1976.

**Small dirt strip airport-activity unknown.

size, gas consumption, time of operation, and rate of particulate emission for heater treaters were adopted from a previous study (PEDCo 1975). The emissions generated by heater treaters are summarized in Table R4-15.

Data relating to natural gas compressors were obtained by contacting the major pipeline operators in the ES region (Brandt 1976; Graham 1976; Curtis 1976; Wheeler 1976; Bell 1976; McLanehan 1976; Brown 1976; Stuart 1976; Biehwig 1976). Information compiled included number, location, horsepower rating, and fuel consumption estimates for each compressor unit. Emission rates were computed based on methods developed by the EPA (1973b). Emissions for gas compressors in the ES region are presented in Table R4-16.

Total emissions for industrial processes area sources calculated for 1976 (tons per year) are:

County	Emissions
Sweetwater*	38
Lincoln	5
Uinta	5

Point Sources. The information compiled regarding the 1975 particulate emissions of industrial point sources was obtained from the Wyoming DEQ (Russell 1976; Collins 1976). Table R4-17 lists the industrial point sources located in the ES region and emissions generated by these sources.

Existing Coal Mines

Because of the wide variation of mining procedures used in 1975 at existing mines, as well as the relatively small contribution made by these mines to the region-wide particulate emissions burden, it was not feasible to analyze existing mines on the same level of detail applied to the proposed mines. Therefore, a composite emission factor, expressed in terms of pounds of fugitive dust per ton of coal production, was estimated from the analysis performed for the five proposed mines. Separate emission factors were derived for surface and underground mines in the eastern (Sweetwater) and western (Lincoln/Uinta) portions of the ES region. Because the base year (1975) predated much of the recently enacted environmental legislation and, in particular, the 1977 Wyoming regulations for dust control at coal processing sites, these base year factors were derived by recalculating the emissions at the proposed mines that would have been predicted if all processing and coal handling controls were relaxed; i.e., all dust control measures except for watering

TABLE R4-15

CALCULATED 1975 HEATER TREATED PARTICULATE EMISSIONS

County	Units	Average Emissions per unit (tons per year)	Total Emissions (tons per year)
Sweetwater*	127	0.205	26
Lincoln	15	0.205	3.1
Uinta	2	0.205	0.4

*That portion of Sweetwater County within the ES region.

TABLE R4-16

1975 PARTICULATE EMISSIONS FROM GAS COMPRESSORS

County	Compressors	Total Fuel Consumption ($10^6 ft^3$)	Average Emission Rate (pounds per $10^6 ft^3$)	Total Emissions (tons per year)
Sweetwater*	13	2375.4	10	12
Lincoln	6	462.4	10	2.3
Uinta	7	835	10	4.2

*That portion of Sweetwater County within the ES region.

TABLE R4-17

1975 PARTICULATE EMISSIONS GENERATED BY INDUSTRIAL POINT SOURCES

(tons per year)

County	Source Name	Total Plant Emissions (tons per year)
Sweetwater**	Allied Chemical	1,432
	Church and Dwight	98
	Columbine	115
	FMC (Green River)	1,202
	Stauffer Chemical (Green River)	634
	Bridger	774*
	Texas Gulf	NA
	Total	4,255
Lincoln	Naughton	8,700
	FMC (Kemmerer)	471
	Stauffer Chemical (Kemmerer)	7,603
	Total	16,774
Uinta	Wasatch Forest Company	70

NA = Not available.

*One unit operating and one unit in start-up mode.

**That portion of Sweetwater County within the ES region.

of unpaved roads, which has been routinely practiced at coal mines for some time. Thus, in the event that one or more of the existing mines was implementing processing dust control measures in 1975 that were assumed for the Proposed Action, the resultant base year emissions from existing mines may have been overestimated. The effect on the overall emissions burden should amount to no more than 2 to 3% for Lincoln/Uinta Counties and less than 1% for Sweetwater County. This is far less than the range of error inherent in the emission factors used for the various mining activities.

Composite emission factors for surface and underground mines in the two ES subregions considered are given in Table R4-18. Calculated 1975 particulate emissions from existing mining are shown in Table R4-19.

Agriculture

A major portion of the fugitive dust associated with agricultural activities is generated by tillage operations and by wind-blown dust from tilled land. To determine the magnitudes of these sources, the approximate location, crop type, and acreage planted for each county in 1975 was obtained (Hartley 1976; Wyoming Department of Agriculture 1976).

Total acreage of various crop types for the ES region are shown in Table R4-20.

The emission equation used to calculate fugitive dust from tillage (EPA 1974) is:

$$E_{tillage} = \frac{1.4\ S\left(\frac{V}{5.5}\right)}{\left(\frac{PE}{50}\right)^2} \qquad \text{(R4-4)}$$

where E is the emission factor (pounds per acre)

S is the silt content of surface soil (percent)

V is the tillage implement speed (mph)

PE is the Thornthwaite's precipitation-evaporation index [taken to be 33 for the entire ES region, based on regional data provided by EPA (1975)]

TABLE R4-18

COMPOSITE EMISSION FACTORS FOR EXISTING COAL MINES

Subregion/Mine Type	Composite Emission Factor	Proposed Action Mines Used for Basis of Derivation
Sweetwater County		
Surface Mines	2.20	Black Butte
Underground Mines	1.14	Long Canyon
Lincoln/Uinta Counties		
Surface Mines	2.33	North Block, Twin Creek, South Haystack

TABLE R4-19

CALCULATED 1975 PARTICULATE EMISSIONS FROM EXISTING MINES

Mine	Mine Type	Coal Produced (tons per year)	Emissions (tons per year)
Sweetwater County			
Bridger	Surface	1.9	2,090
Rainbow-Columbine	Underground	0.12	68
Stansbury	Underground	0	0
Total		2.02	2,158
Lincoln County			
North Haystack	Surface	0	0
South Block	Surface	2.7	3,146
Total		2.7	3,146

TABLE R4-20

TOTAL ACRES PLANTED IN 1975

Crop	Sweetwater (west)	Lincoln	Uinta
Wheat	-	3,400	200
Barley	350	18,600	100
Oats	900	800	200
Hay	21,400	82,600	52,400
Alfalfa	12,800	43,200	5,500
Corn	-	100	-
Total	35,450	147,700	58,400

For this study, it was assumed that average tillage implement speed was 5.5 mph. Average silt content for the region was estimated to be 30%. The emission factor was corrected to consider only particulates likely to remain suspended (i.e., particulate diameter less than 30 μm) by introducing a multiplying factor of 0.8 (EPA 1974). It was assumed that all cropland, other than hay and alfalfa, was tilled once per year. The calculated total emissions generated by agricultural tillage are shown in Table R4-21.

The equation used to compute the emission factor from windblown dust (EPA 1974) is:

$$F_{windblown} = IKCL'V'a \qquad (R4-5)$$

where E is the suspended particulate fraction of wind erosion losses of tilled fields (tons per acre per year)

a is the portion of wind erosion losses that would be measured as suspended particulates, estimated to be 0.025

I is the soil erodibility (tons per acre per year)

K is the surface roughness factor, dimensionless

L' is the unsheltered field width factor, dimensionless

V' is the vegetative cover factor, dimensionless

The EPA document (1974) provides developmental discussions and values for these factors. A somewhat more detailed discussion is contained in the section on methods for determining coal mine emissions. Values of these factors specific to the region are presented in Table R4-22. Total windblown dust emissions for each county were computed as the product of the specific emission factor and associated cropland acreage.

Windblown particulate emissions are listed in Table R4-23.

The calculated emissions from agricultural activites (tons per year) are:

Sweetwater	Lincoln	Uinta
456	4,317	1,291

TABLE R4-21

1975 AGRICULTURAL TILLAGE EMISSIONS

County	Total Acres	Emission Factor (tons per acre per year)	Emissions (tons per year)
Sweetwater	1,404	0.050	70
Lincoln	22,900	0.050	1,145
Uinta	500	0.050	25

TABLE R4-22

AGRICULTURAL EMISSION FACTORS

County/Crop	Emission Factor						
Sweetwater	I	K	C*	L'	V'	a	E
Wheat	86	0.6	0.37	0.82	0.04	0.025	0.015
Barley	86	0.6	0.37	0.82	0.07	0.025	0.026
Oats	86	0.8	0.37	0.90	0.02	0.025	0.011
Hay	86	0.8	0.37	0.90	0.02	0.025	0.011
Alfalfa	86	1.0	0.37	0.85	0.001	0.025	0.001
Lincoln							
Wheat	86	0.6	1.09	0.82	0.04	0.025	0.046
Barley	86	0.6	1.09	0.82	0.07	0.025	0.081
Oats	86	0.8	1.09	0.90	0.02	0.025	0.034
Hay	86	0.8	1.09	0.90	0.02	0.025	0.034
Alfalfa	86	1.0	1.09	0.86	0.001	0.025	0.001
Corn	86	0.6	1.09	0.82	0.56	0.025	0.65
Uinta							
Wheat	86	0.6	1.09	0.82	0.04	0.025	0.046
Barley	86	0.6	1.09	0.82	0.07	0.025	0.081
Oats	86	0.8	1.09	0.90	0.02	0.025	0.034
Hay	86	0.8	1.09	0.90	0.02	0.025	0.034
Alfalfa	86	1.0	1.09	0.85	0.001	0.025	0.001

*Computed value C = 0.345 (μ^3/PE^2) where μ = average annual wind speed by county and PE is Thornthwaite's precipitation-evaporation index.

TABLE R4-23

1975 WINDBLOWN PARTICULATE EMISSIONS

(tons per year)

Crop	Sweetwater	Lincoln	Uinta
Wheat	-	107	7
Barley	14	1,046	6
Oats	15	19	4
Corn	-	45	-
Hay	356	1,951	1,248
Alfalfa	1	4	1
Total	386	3,172	1,266

Construction

Construction activities disturb the land surface, which results in wind erosion of exposed soils and direct generation of fugitive dust emissions by construction-related activity. An emissions factor of 1.2 tons per acre per month for construction activities was determined for desert construction sites (EPA 1974). This factor was adjusted for the ES region by the ratio (EPA 1974):

$$\frac{(\text{PE Experiment})^2}{(\text{PE - ES Region})^2} = \frac{(31)^2}{(33)^2} = 0.88 \qquad \text{(R4-6)}$$

where PE is the Thornthwaite precipitation-evaportion index (Thornthwaite 1931).

Thus, for the ES region, the construction emission factor is:

$$\frac{(31)^2}{(33)^2} \times 1.2 \text{ tons per acre per month} = 1.06 \text{ tons per acre per month}$$

These adjusted factors were multiplied by the total disturbed acreage (acres) and by the duration of construction activity (months) to yield the construction-related emission totals listed in Table R4-24. Information relating to highway construction was obtained from the WSHD (Garrett 1976). The highway data are summarized in Table R4-25. County and city planning agencies were contacted for data regarding residential, commercial, and public construction projects (Watt 1976; Tarno 1976; Koritnic 1976; Payne 1976). In some cases, actual disturbed acreage values were obtained for residential and commercial construction. Otherwise, it was estimated that each new residential home or trailer disturbed one-sixth of an acre, and each commercial construction disturbed one-fourth of an acre. Actual disturbed acreage values for public construction were obtained for each project. Estimates of acreage disturbed for industrial construction were obtained from several sources (Burlson 1976; Russell 1976).

Open Burning

Open burning emission sources include the burning of oil sumps (spilled raw petroleum), flaring of natural gas, slash burning, agricultural burning, and forest and range fires. Emissions from the flaring of natural gas have been deleted because of the relatively low emissions involved and because of the gross uncertainties in estimating the quantity of gas burned. Agricultural burning was not included since it is not ordinarily practiced in Wyoming (Russell 1976).

TABLE R4-24

CALCULATED 1975 CONSTRUCTION-RELATED PARTICULATE EMISSIONS

County	Construction Type	Acres Disturbed	Months	Emission Factor	Emissions (tons per year)
Sweetwater	Residential	350	6	1.06	2,226
	Commercial	30	6	1.06	191
	Public	189	9	1.06	1,803
	Industrial	800	9	1.06	7,632
	Highway	See Table R4-25		1.06	423
	Total				12,275
Lincoln	Residential	20	6	1.06	127
	Commercial	-	-	1.06	-
	Public	-	-	1.06	-
	Industrial	-	-	1.06	-
	Highway	See Table R4-25		1.06	362
	Total				489
Uinta	Residential	70	6	1.06	445
	Commercial	-	-	1.06	-
	Public	-	-	1.06	-
	Industrial	-	-	1.06	-
	Highway	See Table R4-25		1.06	41
	Total				486

TABLE R4-25

1975 HIGHWAY CONSTRUCTION

	Project	Construction Type	Construction Factor	Months	Total Acres
Sweetwater	I-80	Reconstruction	0.33	4	12.80
	WYO-330	Reconstruction	0.33	7	7.92
	WYO-530	Reconstruction	0.33	8	3.60
	#6 Road Bridge	New	1.00	5	1.80
	Blairtown-Flaming Gorge Rd.	Reconstruction	0.33	8	30.96
	WYO-414	Reconstruction	0.33	7	42.48
	Rock Springs streets	Reconstruction	0.33	6	7.92
	WYO-530	Reconstruction and bridge construction	0.66	6	5.04
	Texas-Gulf Sulfur Rd	Reconstruction	0.33	6	65.52
Lincoln	US 89	Reconstruction	0.33	12	50.40
	Cokesville-Southwest Rd	Reconstruction	0.33	4	43.20
	Fontevelle Creek Rd	Reconstruction	0.33	3	84.96
Uinta	Evanston Marginal I-80	Reconstruction	0.33	8	14.40

Information concerning forest, slash, and range fires was obtained from several sources (Russell 1976; Stillman 1976; Quinn 1976; Durfey 1976; Hersh 1976; Steinbreck 1976). It was estimated that an average of 30 tons of material are consumed per acre burned for forest and slash fires and 2 tons per acre for range fires (Hersh 1976). The reported acres burned in 1975 are:

County	Forest and Slash	Range
Sweetwater	-	-
Lincoln	-	30
Uinta	-	30

Oil sump fire information was extracted from the Open Burning Log (Wyoming DEQ 1976) maintained by the Wyoming Department of Environmental Quality. Total barrels of oil burned in 1975 are:

	Barrels Burned
Sweetwater	110
Carbon	-
Uinta	-

Total calculated particulate emissions from open burning in 1975 are:

Fire	Acres/Barrels Burned	Emissions (tons per acres per barrel)	Total Emissions (tons per year)
Oil Sump	110	0.0017	0.19
Forest	-	-	-
Range	60	0.017	1.02

Aggregate Storage Piles

An inventory of the various types of aggregate stockpiled within the ES region was compiled. The WSHD provided information on aggregate piles maintained by the department throughout the state (Harnish 1976). Sand and gravel producers were contacted individually to determine their

average annual stockpiled inventory (Fryberger 1976; Benett 1976; Kiewit 1976; Rawlins 1976). A few suppliers were reluctant to provide this information. In these cases, a value equal to 90% of the suppliers' annual production (Koch 1976) was used to approximate their inventory. Estimated total sand and gravel stockpiles maintained in the ES region are shown in Table R4-26.

Very substantial quantities of stockpiled aggregate are associated with the trona and phosphate industries in the ES region. Data representative of the trona stockpiles were acquired from several sources (Burlson 1976; Peverley 1976; Garland 1976; Kennison 1976). Total trona stockpiling was estimated to be 1,200,000 tons. Phosphate stockpiles were estimated to be 450,000 tons (Stauffer 1976).

Total aggregate storage in the ES region are listed in Table R4-27.

The EPA has prepared an equation to approximate emissions from aggregate stockpiles (EPA 1974):

$$E_{(\text{aggregate})} = \frac{0.33}{(PE/100)^2} \qquad \text{(R4-7)}$$

where E is the emissions (pounds per ton of aggregate)

PE is the Thornthwaite's precipitation-evaporation index (taken to be 33 for the entire ES region)

This relationship includes emissions from all related activities, such as loading onto the piles, vehicular traffic, wind erosion, and load out from the piles.* It was assumed that the emission relation, which is based on studies of sand and gravel operations in the Midwest, would provide a reasonable estimate of emissions from the various aggregate material stockpiles in the ES region. The total emissions are shown in Table R4-28.

Future Particulate Emissions in the ES Region

In general, the available data pertaining to anticipated changes in particulate emissions for 1980 and thereafter were extremely limited. An attempt was made, therefore, to scale the base year (1975) emissions for each source category according to surrogate data such as population growth, the change in employment for a particular sector (e.g., industrial,

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*Since this emission calculation is not stratified by these various activities, it is not possible to calculate that portion if the emission from aggregate transfer. A portion of emissions due to aggregate transfer has already been considered in the point inventory. However, current data does not allow the stratification of this information.

TABLE R4-26

1975 SAND AND GRAVEL AGGREGATE

(tons)

	Sweetwater	Lincoln	Uinta
Highway	35,000	34,000	26,000
Industrial	350,000	0	10,000
Total	385,000	34,000	36,000

TABLE R4-27

ESTIMATED 1975 AGGREGATE STOCKPILES

(tons)

County	Sand and Gravel	Trona	Phosphate
Sweetwater	385,000	1,200,000	-
Lincoln	34,000	-	450,000
Uinta	36,000	-	-

TABLE R4-28

CALCULATED 1975 PARTICULATE EMISSIONS FROM AGGREGATE STOCKPILES

County	Total Aggregate (tons per year)	Emission Factor (pounds per ton per year)	Total Emissions (tons per year)
Sweetwater	1,585,000	3.03	2,401
Lincoln	484,000	3.03	733
Uinta	36,000	3.03	55

agricultrual), industrial production, etc. The principal objective of the future year emissions burden analysis is to develop future year scale factors. These scale factors will then be applied to baseline air quality data to provide clues as to the trends in regional TSP air quality, as well as approximate ranges in concentrations to be expected in the 1975 to 1990 time period.

Because the existing monitoring data base in Uinta County was judged to be insufficient for estimating annual and second highest 24-hour TSP concentrations, the ultimate TSP air quality ranges and trends predicted for Lincoln County (based on Lincoln County samplers) are taken to be representative of the western portion of the ES region (i.e., Lincoln and Uinta Counties) as a whole. Thus, scale factor computations are based on emissions from sources in Lincoln and Sweetwater Counties, including the urban areas of Rock Springs and Green River.

Results of the emissions burden analysis are summarized in Table R4-29. The basis (type of surrogate data) for the projection of emissions from each source category is summarized in Table R4-30.

The data available and the impact of these changes on regional TSP concentrations are discussed in the following paragraphs.

Fuel Consumption by Stationary Sources

The particulate sources under this grouping include :

- Bituminous Coal
- Distillate Oil
- Residual Oil
- Natural Gas
- Liquified Petroleum Gas (LPG)
- Wood

Fuel distributors had no data to indicate the magnitude of their sales in 1980, 1985, and 1990. Additionally, limited data were available for projecting fuel sales in future years. Strictly speaking, future emissions will be affected by changes in the mix of fuels consumed, which, in turn, is influenced by such factors as availability, environmental regulations, and the relative growth of various industrial sectors. Because particulate emissions from stationary fuel consumption sources constitute only a very small portion of the total particulates generated

TABLE R4-29

FUTURE PROJECTIONS OF PARTICULATE EMISSIONS FOR LINCOLN AND SWEETWATER COUNTIES EXCLUSIVE OF NONEXISTING COAL MINES

(tons per year)

Source Category	Lincoln County				Sweetwater County			
	1975	1980	1985	1990	1975	1980	1985	1990
Fuel Consumption	167	244	279	281	116	158	168	171
Transportation								
Roadway Vehicles								
Exhaust	94	137	157	158	409	556	593	601
Paved Roads	667	974	1,114	1,121	3,043	4,138	4,412	4,473
Unpaved Roads	9,208	11,072	13,031	12,942	27,783	37,700	40,405	40,987
Off-Roadway Vehicles	13	10	9	9	11	8	8	8
Railroads	*	**	†	†	*	**	†	†
Aircraft	§	§	§	§	§	§	§	§
Industrial Processes								
Area Sources	5	7	8	8	38	57	64	64
Point Sources	16,774	13,829	14,749	14,749	4,255	5,531	5,531	5,531
Existing Coal Mines	3,144	3,736	3,736	3,736	2,106	5,218	5,264	5,264
Agriculture	4,317	2,461	2,330	2,245	456	424	420	410
Construction								
Population Dependent	127	1,240	33	–	4,220	3,050	990	165
Industrial	–	3,180	–	–	7,632	–	–	–
Highway	362	362	362	362	423	423	423	423
Aggregate Storage								
Sand and Gravel								
Industrial	–	226	–	–	529	–	–	–
Highway	52	52	52	52	53	53	53	53
Trona	–	–	–	–	1,819	3,638	3,638	3,638
Phosphate	681	681	681	681	–	–	–	–
Open Burning	§	§	§	§	§	§	§	§
Total All Categories(d)††	35,611	38,211	36,541	36,344	52,893	60,954	61,969	61,788
Scale Factor(f)§§	1.0	1.07	1.03	1.02	1.0	1.15	1.17	1.17

[*] Regionwide total: 339 tons per year.

[**] Regionwide total: 542 tons per year.

[†] Regionwide total: 563 tons per year.

[††] Excluding railroad emissions.

[§] Negligible regionwide total.

[§§] Ratio to 1975 emissions burden.

TABLE R4-30

BASIS OF PROJECTIONS FOR INDIVIDUAL SOURCE COMPONENTS OF OVERALL ES REGION PARTICULATE AIR QUALITY FOR 1980, 1985, AND 1990

Source Category	Basis of Future Projections (1980, 1985, and 1990)
Fuel Consumption by Stationary Sources	Proportional to population in each county (all subcategories).*
Transportation	
Roadway Vehicles	
Exhaust Emissions	Proportional to population in each county.*
Paved Roads	Proportional to population in each county.*
Unpaved Roads	Proportional to population in each county subregion.*
Off-Highway Vehicles	Proportional to employment (farm sector) in each county.*
Railroads	Growth assumed negligible (constant emissions) for ES region.
Aircraft	Not evaluated - emissions negligible.
Industrial Processes	
Area Sources	Proportional to employment (industrial sector) in each county.*
Point Sources	Total emissions estimated for each county based on available information on planned expansion and emission controls.
Existing Coal Mines	Based on projected annual coal tonnage figures for each mine, assumed implementation of dust controls and composite emission factors developed for proposed action mines.
Agriculture	Proportional to employment (farm sector) in each county.*
Construction	
Residential	Proportional to annual population growth in each county subregion.*
Commercial	Proportional to annual population growth in each county subregion.*
Public Facilities	Proportional to annual population growth in each county subregion.*
Industrial	Attributed entirely to expansion of local power plants.
Highway	Growth assumed negligible (constant emissions).
Aggregate Storage	
Sand and Gravel	
Industrial	Assumed to be 7% of industrial construction emissions.**
Highway	Growth assumed negligible (constant emissions).
Trona (Sweetwater only)	Doubling of production between 1975 to 1980, constant thereafter.
Phosphate (Lincoln only)	Constant rate of production assumed for 1975 to 1990.
Open Burning	Not evaluated - emissions negligible.

*Growth rate for that portion of Sweetwater within the ES region is assumed to be the same as for the county as a whole.

**Based on 1975 analysis for Sweetwater County.

within the ES region (based on 1975 calculations), the growth in total particulate emissions from stationary fuel sources in each county are assumed to be proportional to population increases between 1975 and 1990.

Transportation and Vehicular Sources

The particulate sources in this grouping include the following categories:

- Vehicular
- Unpaved Roads
- Dust from Paved Roads
- Railroads
- Aircraft

Of these sources, the most significant is unpaved roads. The WSHD did not have any data to indicate any change in ADT, increase/decrease in miles of unpaved roads, or change in average vehicle speeds on unpaved roads. Unpaved road emission in 1975 were computed for the urban and rural areas of each county in the ES region from data made available by the WSHD. Emissions were assumed to increase in proportion to population in each county subregion and are estimated using the formula:

$$E_{URj} = \sum_k G_{Pjk} E_{URBk} \qquad \text{(R4-8)}$$

where E_{URj} is the unpaved road emissions estimated for year j (county wide)

E_{URBk} is the unpaved road emissions computed for base year (B = 1975) and county subregion k for which VMT data was available

G_{Pjk} is the population growth factor for year j and county subregion k - ratio of subregion population in year j to subregion population in 1975.

The subregions considered are as follows:

Sweetwater County (Rock Springs, Green River, and all of rural Sweetwater County contained within the ES region)

Lincoln County (Kemmerer, all of rural Lincoln County)

The 1975 results indicate that the dominant contributions to unpaved road VMT (hence, unpaved road fugitive dust emissions) are from vehicles traveling outside the three urban areas. In the rural areas, unpaved roads generally provide access from major (paved) roadways to isolated residences and are routinely used for this purpose. If it can be assumed that new residents of the rural areas in the ES region would primarily be employed by the mines and would, therefore, reside in locations with immediate access to paved highways, then the growth rates assumed for unpaved road emissions probably overestimate the actual situation.

The one transportation-related particulate source for which data were available beyond 1975 was railroads. The Union Pacific Railroad (Catalan 1976) indicated that coal haulage within the area of interest is projected to increase by 10% per year up to 1980. Any further increase in haulage after this period would be associated with coal haulage from the proposed mines. The 1975 emission burden associated with railroad activities was adjusted to reflect the 10% per year growth. The emissions associated with coal haulage from the proposed mines were also calculated.

The expected particulate emissions from fuel burned by trains hauling coal from the proposed mines were determined by the application of fuel usage and emission factors to the total train mileage within the study area in 1980, 1985, and 1990 (see Table R4-31). The assumptions were made that all trains, with the exception of local trains, would be transporting coal to destinations outside of the BLM study areas and that local trains would travel approximately ten miles (Karbs 1976). The following equation indicates the relationship between fuel usage and total train mileage:

$$\text{Fuel Usage} = (\text{Number of trains})(2{,}191 \text{ gallon per } 1{,}000 \text{ tons mile})(10{,}000 \text{ tons per train})(\text{mileage}) \qquad (\text{R4-9})$$

The number of trains departing from each operational mine site was obtained from each of the mine plans submitted to the BLM. The fuel consumption factor, the average gross tonnage per unit train, and the mileage points were obtained from the Union Pacific Railroad (Catalan 1976).

The mileage was determined from travel distance between the train station nearest each mine site and the limits of the ES region along the railway route, Table Rock to the east, and the Idaho or Utah border to the west. Since data were not available for comparison of the number of westbound trains traveling the shorter route to Idaho compared to the number traveling the longer route to Utah, a conservative emission assumption was used; all coal-bearing trains, with the exception of those loading coal at Kemmerer, travel to Utah.

TABLE R4-31

TOTAL PARTICULATE EMISSIONS IN ES REGION FROM COAL-BEARING RAILROAD TRAINS

Mine	Direction of Travel	Loading Point	Number of Miles** Traveled per Train	Number of Trains per Year	Fuel Usage (gallons)	Particulate Emissions (tons per year)
Black Butte	E	Black Butte	19.2	350	147,235	1.8
	W		226.92	350	1,740,136	21.8
Long Canyon	E	U.S.Steel*	64.9	100	142,196	1.8
	W		200.22	100	438,682	5.5
North Block*	L	Local	10.0	140	30,674	0.4
South Haystack	W	Kemmerer	52.68	350	403,977	5.0
Twin Creek	E	Bridger	139.03	100	304,615	3.8
	W		107.09	150	351,951	4.4

*Not operational until 1981.

**Within the ES region.

Particulate emissions were determined from total fuel usage by the application of the EPA emission factor, 25 pounds per 1,000 gallons of fuel. The following table indicates the total particulate emissions for 1980, 1985, and 1990 from coal haulage from the proposed mines within the southwestern ES region and the additional emissions from trains passing through the area from proposed mines in the southcentral ES region (see Table R4-32).

The total calculated particulate emissions (tons per year) from railroad activities within the ES region are:

1980	542.5
1985	563.1
1990	563.1

Industrial Processes

Point Sources. Each of the existing industrial point sources was contacted to obtain data regarding future emissions. In most instances, data were not available. However, some industrial sources did provide data on changes in emissions by 1 June 1977. Jim Bridger and Naughton Power Plants data, moreover, was supplied by the Wyoming DEQ (Russell 1978) for 1980, 1985, and 1990 in sufficient detail to enable particulate emissions to be estimated for these years. Particulate emissions from industrial point sources as of 1 June 1977 are listed in Table R4-33. Stack parameters and emissions estimates for the Jim Bridger and Naughton Power Plants are presented in Table R4-34.

Area Sources. The emission sources included in this category are heater treaters and gas compressors and are widely dispersed. Unless new emission controls are imposed, emissions from these sources will vary in proportion to oil and gas production. There are no available data to indicate changes in oil or gas production. However, the magnitude of the emissions from the sources indicates a very small contribution to the total emission burden. Therefore, it is assumed that the growth in this category of emissions will vary in proportion to industrial sector employment for each county.

Existing Coal Mines

Particulate emissions from mines existing prior to 1978 and expected to continue operation after 1980 were estimated based on the composite emission factors (pounds of fugitive dust per ton coal mined) developed for the five proposed and two projected mines. Separate composite factors were computed for three mine subclasses: surface mines in

TABLE R4-32

TOTAL PARTICULATE EMISSIONS IN ES REGION FROM COAL-BEARING TRAINS TRAVELING FROM BOTH PROPOSED MINING AREAS

Source of Coal-Bearing Trains	Total Particulate Emissions (tons per year)	
	1980	1985 and 1990
Southwestern ES Region	44.1	44.5
Southcentral ES Region	3.4	23.6
Total Impact of Coal-Bearing Trains	47.5	68.1

*This spur of the Union Pacific Railroad track extends 9.5 miles north of Rock Springs to the U.S. Steel loading point.

TABLE R4-33

PROJECTED PARTICULATE EMISSIONS FROM INDUSTRIAL POINT SOURCES AS OF 1 JUNE 1977

County	Source Name	Emissions (tons per year)	Percentage Change from 1975
Sweetwater	Allied Chemical	939.5	
	Church and Dwight	98.0	
	Columbine	115.0	
	FMC (Green River)	1,125.0	
	Stauffer Chemical (Green River)	520.0	
	Bridger	2,228.0*	
	Texas Gulf	NA	
	Total	5,025.5	+18
Lincoln	Naughton	8,700.0**	
	FMC (Kemmerer)	471.0	
	Stauffer Chemical (Kemmerer)	229.0	
	Total	9,400.0	-44
Uinta	Wasatch Forest Company	70.0	0

*Assuming all four units are operating.

**Expected to be less but by an unknown amount. Therefore, it was assumed to be constant. In addition, there will be one additional unit added in 1982 and one in 1984. There are no data concerning these two new units.

NA - Not Available

TABLE R4-34

STACK HEIGHTS AND PROJECTED TSP EMISSIONS FOR NAUGHTON AND JIM BRIDGER POWER PLANTS

Unit	Naughton Power Plant			Jim Bridger Power Plant		
	Assumed Initial Year of Operation	Stack Height (feet)	TSP Emissions (tons per year)	Assumed Initial Year of Operation	Stack Height (feet)	TSP Emissions (tons per year)
No. 1	IO	200	79	IO	500	1,424
No. 2	IO	225	858	IO	500	1,424
No. 3	IO	250	4,818	B1980	500	1,424
No. 4	1982	600	459	B1980	500	1,424
No. 5	1984	600	459	-	-	-

IO - In operation.

B1980 - To be operating before 1980.

Sweetwater County, surface mines in Lincoln/Uinta Counties, and underground mines (region wide). The 1975 factors were calculated from the weighted average of the 1985 and 1990 factors evaluated for all the mines in each subclass with all controls relaxed except watering of unpaved roads and land reclamation. The factors used to evaluate emissions from existing mines in 1980, 1985, and 1990 were computed in the same manner, without relaxation of any controls. Thus, it is assumed that the bulk of dust controls associated with processing and coal handling would be implemented at existing mines sometime between 1975 and 1980. The maximum error generated by this assumption is less than 5% of the total burden for either subregion; that is, far less than the level of uncertainty for the overall emissions methods.

Results are summarized in Table R4-35. As indicated, the most significant change would be for Sweetwater County due to the fourfold increase in coal output projected for the Bridger Mine. A significant (75%) increase in coal production for Lincoln/Uinta County mines is also projected. However, because of the assumed implementation of processing and handling controls, this translates into only a 20% increase in fugitive dust emissions from these mines.

Agriculture

In the absence of more definitive information, total fugitive emissions from agricultural tilling and wind erosion are assumed to be proportional to farm sector employment. Because a significant percentage of this sector is expected to be absorbed by the mining industry, the agricultural emissions burdens in both subregions decrease steadily from 1975 to 1990. This is consistent with the assumption that large amounts of the region's limited water supply would probably have to be diverted from irrigation of cropland to mine reclamation, industrial, and residential uses. The impact of the change on TSP levels would be determined by the degree to which water resources are diverted.

Construction

To evaluate future year particulates emissions, construction activities are divided into three subclasses: population-dependent construction (residential, commercial, and public facilities), industrial construction, and highway construction. Future year emissions from residential, commercial, and public facility construction are taken as proportional to the number of acre-months per year of active construction in each subregion, which, in turn, are assumed to be proportional to the projected annual increase in population. Thus:

$$E_{PDC}(Y) = E_{TAY} * A_P * \Delta Pop.(Y) \qquad (R4\text{-}10)$$

TABLE R4-35

FUTURE PARTICULATE EMISSIONS IN THE ES REGION FROM EXISTING COAL MINES

	Composite Emission Factor (pounds per ton coal)	Annual Coal Production (millions of tons)	Particulate Emissions (tons per year)
Surface Mines			
Sweetwater County			
1975	2.20*	1.9	2,038
1980	1.36**	7.5	5,062
1985	1.36**	7.5	5,062
1990	1.36**	7.5	5,062
Lincoln County			
1975	2.33*	2.7	3,144
1980	1.59**	4.7	3,736
1985	1.59**	4.7	3,736
1990	1.59**	4.7	3,736
Underground Mines			
Sweetwater County			
1975	1.14*	0.12	68
1980	0.31**	1.0	155
1985	0.31**	1.3	202
1990	0.31**	1.3	202
Total Existing Mines			
Sweetwater County			
1975		2.02	2,106
1980		8.5	5,218
1985		8.8	5,264
1990		8.8	5,264
Lincoln County			
1975		2.7	3,144
1980		4.7	3,736
1985		4.7	3,736
1990		4.7	3,736

*Based on estimates for the proposed mines, with all controls relaxed except watering of unpaved roads.

**Based on estimates for the proposed mines, with all controls applied.

where

E_{PDC} is the population-dependent construction emissions of particulates in a given future year Y

E_{TAY} is the construction emission factor for the ES region (of 1.06 tons per acre per month, based on a PE index of 33)

A_P is the annual number of acre-months of construction per unit increase in population

ΔPop.(Y) is the change in population for a particular subregion in the year Y

The proportionality constant A_P was computed by dividing the estimated 1975 residential/commercial/public acre-months for the three counties in the ES region by the estimated 1975-76 population increase for these counties. Thus:

$$A_P \simeq 4524/2967 = 1.52$$

Results for population-dependent construction emissions are given in Table R4-36.

Particulate emissions associated with the future construction of industrial facilities were extremely difficult to estimate because of the uncertainty of future industrial expansion in the ES region. Therefore, construction emissions were estimated for only a single facility - the planned additions to the Naughton Power Plant in Lincoln County. According to Mr. Frank Davis (1978) of UP&L, all units should be completed before 1985, with only Unit 4 under construction in 1980. Assuming that 250 acres would be under active construction for all of 1980, it is then estimated that 3,188 tons per year of fugitive dust would be generated from Naughton Unit 4 construction in that year only.

Highway construction is dependent on the amount of new and/or reconstructed roads. Since the highway construction that occurred in 1975 was almost all reconstruction, it is assumed that this situation is representative of the long term. Therefore, the region-wide emissions burden from highway construction is not expected to vary significantly in future years.

Aggregate Storage

This category is composed of four main sources:

- Highway sand and gravel
- Industrial sand and gravel
- Trona aggregate
- Phosphate stockpiles

TABLE R4-36

POPULATION DEPENDENT CONSTRUCTION EMISSIONS

	Sweetwater County	Lincoln County
Estimated Population Increase		
1975	2,600	125
1980	1,850	750
1985	600	20
1990	100	0
Population-Dependent Construction Emissions		
1975	4,300	206
1980	3,050	1,240
1985	990	33
1990	165	0

It is expected that there will be little change in highway sand and gravel aggregate. Industrial sand and gravel aggregate will vary in proportion to construction activity. Based on the 1975 data for Sweetwater County (the only subregion that experienced a significant amount of industrial construction activity in that year), fugitive emissions from sand and gravel piles at construction sites were about 7% of construction activity emissions. It was assumed that this figure is representative of industrial sand and gravel for the ES region. Hence, only those emissions from sand and gravel stockpiled in Lincoln County for the construction of Naughton Unit 4 in 1980 were estimated.

Approximately 20% of annual production of trona is stockpiled at any one time. Therefore, TSP concentrations in the trona patch will vary in proportion to production, which is expected to double between 1975 and 1980 and remain relatively constant after that time. The amount of phosphate stockpiled is about 40% of the annual phosphate production. Therefore, TSP concentrations in the vicinity of the phosphate stockpiles will vary with production. No projections are available, indicating that phosphate production will increase by 1980 or thereafter. The rate of production is thus assumed constant for the purposes of this analysis.

Open Burning

This category is divided into four categories of fires:

- Oil sump
- Range
- Forest
- Agricultural

In the case of oil sumps (spills) without improved handling, oil spills will vary roughly in proportion to oil production. Agricultural fires are not considered feasible in Wyoming; therefore, their impact is negligible. There may be a slow increase in range and forest fires associated with population growth. This would be due to the greater likelihood of man-made fires. Even with the possible increase in emissions related to this situation, open burning will not have a significant effect on regional TSP concentrations.*

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*Excluding a massive forest fire.

Fugitive Dust Emissions from Coal Mining

Many of the operations associated with coal mining constitute significant sources of fugitive dust that, in turn, contribute to elevated ambient particulate levels in the vicinity of the mine. Activities analyzed in this study are enumerated below.

- Overburden removal and handling associated with interim storage at spoils dumps
- Removal of coal from seam and truck loading
- Truck dumping of coal
- Crushing and screening
- Coal transfer operations
- Haul road and access road traffic and maintenance operations
- Wind erosion from disturbed and exposed land
- Reclamation operations
- Wind erosion from aggregate storage of coal

It is evident that some of these activities overlap. For example, overburden removal and storage necessarily involve truck dumping and wind erosion from spoils dumps.

The subject of fugitive dust emissions from mining operations is currently under intensive investigation. Nonetheless, fugitive dust emissions remain among the most difficult to predict of all major primary pollutants for the following reasons.

- The wide variability in specific mining operations as well as the relative mix of activities at different mines. This variability is attributable to such factors as coal type, the thickness and configuration of the coal seam and overburden, the justification for a given level of capital (equipment) expenditure in relation to potential markets, and the degree of adherence to good engineering and equipment handling practices (exclusive of specific dust control techniques).
- The limited data base currently available for the derivation and statistical calibration of quantitative relationships between fugitive emissions and mining activities.
- The difficulty of isolating the contributions of dust from various activities routinely carried on in a surface or underground mine.
- The wide variability in particle mass distributions, rendering especially difficult the problem of predicting the percentage of initially emitted particles that become permanently suspended in the atmosphere versus those that undergo "fall out" within certain distances.

Aside from the relatively large error inherent in state-of-the-art emission prediction methodology, additional uncertainties arise depending on the ultimate adherence of each mine to its stated mode of operation, as well as its mining sequence and reclamation plans. For some of the mines, such plans were still in the formative stages at the time this analysis was conducted. Even in those cases where detailed plans had been formulated, deviations are possible in the future because of such factors as uncertainties in pre-operation geological surveying, labor strikes, the development of new mining technologies, a significant change in the projected markets for western coal, or new state or federal environmental regulations.

No attempt has been made in this investigation to evaluate the potential uncertainties inherent in the mining plans, although these uncertainties are recognized in those instances where the ultimate impact on annual emissions would be significant. Prediction methodology is, for the most part, not based on particulate sampling at prototype coal mines, but on empirical relationships developed for nonmining sources. Preliminary studies conducted at several western surface mines have indicated, in fact, that for some activities, such as aggregate storage or dragline removal of overburden, errors of an order of magnitude or more are possible.

Because of the serious limitations inherent in state-of-the-art emission factors, the fugitive emissions burdens estimated for proposed and projected coal mines in the southwest Wyoming ES region, along with subsequently derived particulate concentrations, are deemed to be of little or no value in assessing absolute impact in terms of compliance with existing air quality standards. The quantitative results should therefore be viewed as merely a device to be used in a comparative assessment of impact among different coal mines, scenarios, or subregions and for clues as to the appropriate prioritization of mitigating measures. The limitations of each emission factor used in arriving at the total particulate burden for each mine are discussed in more detail at the end of this section.

Sources of Data

In the investigation of the ES region mining scenarios, a number of previous studies were consulted. For the most part, the following publications were relied on:

- Technical Guidance for Control of Industrial Process Fugitive Particulate Emissions. Sections 2.1 and 2.6. U.S. EPA, March 1977 (EPA 1977).
- Evaluation of Fugitive Dust Emissions from Mining. Task 1 Report. PEDCo - Environmental Specialists, Inc., June 1976 (PEDCo 1976).

- Development of Emission Factors for Fugitive Dust Sources. U.S. EPA, June 1974 (EPA 1974).
- Supplement No. 5 for Compilation of Air Pollutant Emission Factors (Second Edition). U.S. EPA, April 1975 (EPA 1975).
- Survey of Fugitive Dust from Coal Mines (Draft Report). Prepared by PEDCo - Environmental Specialists, Inc. for the U.S. EPA, November 1977 (PEDCo 1977).

The last report is an investigation of five coal mines in the high plains and Rocky Mountain regions including a surface mine in southwest Wyoming. Because EPA review of the PEDCo draft (1977) was ongoing at the time of this study, no results from this document were used to compute regional or site-specific emissions estimates for the ES region coal mines. The report was consulted primarily for background information on possible sources and magnitudes of error in deriving fugitive dust emission factors and on the variability of operations at western coal mines. A basic premise of the PEDCo study (1977) is that, for some major activities, fugitive emissions are more a function of the type of equipment employed in a given operation than of the operation per se. Thus, the report presents mine-specific emission factors for dragline and shovel/truck loading operations as opposed to factors for overburden removal (as was done in previous studies), which may involve either draglines or shovels, or a combination of both.

In general, the emission factors used in the current investigation for the various mining activities were obtained from the EPA documents and the PEDCo 1976 report. It is emphasized that the factors presented in these reports were, for the most part, taken directly from several previous studies. These results of studies were, as a rule, obtained by adjusting empirical relations developed for nonmining operations to account for the material and equipment characteristics at a specific coal mine. It is evident, therefore, that errors and inconsistencies may arise from two sources. The first of these is represented by dissimilarities between the prototype coal mine (not accounted for in the adjustments) that the EPA factor is based on and the nonmining activities where the sampling occurred. The second is the potential dissimilarity between the prototype coal mine and the ES region mines. The geological and soil characteristics, as well as the modes of operation at these sites, may bear little resemblance to the proposed mines in the ES region that were analyzed.

Mine-specific information was, for the most part, obtained from the latest available draft version of Chapter 1 of this ES (including the regional report) and from verbal consultation with the Rock Springs office of the BLM as well as the following mine personnel:

Mr. James Wilson (President, Black Butte Coal Company)

Mr. David Englebritson (Peter Kiewit Sons' Company)

Mr. Tait Johnson (Peter Kiewit Sons' Company)

Mr. Jonathan Pachter (Peter Kiewit Sons' Company)

Mr. Eugene Frank (Rocky Mountain Energy Company)

Mr. Brent Walquist (Rocky Mountain Energy Company)

Mr. Wayne Christian (Sunoco Energy Development Company)

Mr. Geslin (Kemmerer Coal Company)

Where no such input was readily available, it was assumed that routine practices at existing surface and underground mines would be employed, except that recently enacted Wyoming regulations for dust control would be implemented as part of the proposed action.

In general, an attempt was made to take a conservative, albeit realistic, approach in the emissions analysis. Consequently, while it is not possible to guarantee that none of the results underestimate the actual situation, the likelihood of overprediction from the composite of all mining activities at a given mine should be higher than that of underprediction. Similarly, the actual composite fugitive emissions should be closer to the lower end of the "error interval" than to the upper end.

Fugitive Dust Emissions from Specific Mining Operations

Fugitive emissions were estimated for all of the coal mining operations identified by the EPA (1977, Table 2-42) as being potential major or minor dust sources with the exception of blasting (a minor source), for which no information was available. The procedures used to evaluate the contribution from each operational category (along with subcategories) are discussed below. Emission factors (pounds of dust per unit of operation) are presented in Table R4-37.

Overburden Removal. Overburden removal is defined as the entire process of removing all soil, earth, and rock material overlying the coal deposit, and placing it back into mined out pits or strips. This process is confined to surface mines and, in a purely strip type operation, these are generally the only activities that involve handling of the overburden material. For either strip or open pit mining, topsoil necessary to support vegetation in the reclamation phase must be stored separately.

The equation used to evaluate the fugitive dust emissions associated with the removal and eventual backfilling of overburden material in a "one-time" stripping operation is given by

$$E_{OBR} = 0.5 * 10^{-3} F_{OBR} P_{OB} \qquad \text{(R4-11)}$$

where

E_{OBR} means emissions (tons per year)

TABLE R4-37

OVERBURDEN REMOVAL AND COAL PRODUCTION ESTIMATES FOR PROPOSED AND PROJECTED ES REGION COAL MINES

Mine	Type	Constant Stripping Ratio*	Amount of Overburden Removed (mm tons per year)**				Annual Coal Production (mm tons per year)			
			1980	1985	1990	EOML†	1980	1985	1990	EOML†
North Block	Surface	2.67	-	5.55	5.55	5.55	-	1.4	1.4	1.4
Twin Creek	Surface	7.21	27.0	27.0	27.0	27.0	2.5	2.5	2.5	2.5
South Haystack	Surface	6.54	15.9	31.8	31.8	26.6	1.5	3.0	3.0	2.5
Black Butte	Surface	††	46.7	59.8	40.0	200.0	5.4	6.6	6.3	3.3
Long Canyon	UG	NA	NA	NA	NA	NA	0.5	2.0	2.0	2.0
Winton	UG	NA	NA	NA	NA	NA	-	2.0	2.0	2.0
Reliance	UG	NA	NA	NA	NA	NA	-	0.5	0.5	0.5

UG means underground.

NA means not applicable.

*Obtained by dividing yd^3 overburden by recoverable coal (tons) over the entire life of the mine.

**Includes only overburden removal directly associated with the mining operation (i.e., overburden removed from spoils dumps is not included).

†End of mine life.

††Overburden tonnage figures are available directly from mine plan.

F_{OBR} means emission factor for overburden removal from Table 2-43 (EPA 1977) (0.048 pounds per ton of overburden)

P_{OB} means mass of overburden material removed (tons per year)

The annual quantity P_{OB} was available only for the Black Butte mine. For the other three surface mines, P_{OB} had to be estimated from a stripping ratio, derived from the total volume of overburden and recoverable coal (tons) estimated for the mine being analyzed. Thus, for these mines, the equation for P_{OB} was given by

$$P_{OB} = p R_S P_C \qquad \text{(R4-12)}$$

where

p is the mass density of overburden, assumed to be about 1.5 tons per yard and both banked and loose overburden*

R_S is the stripping ratio (yard^3 overburden per ton of coal)

P_C is the coal production rate (tons per year)

The emissions Equation (R4-11) is applied automatically to all overburden removed, whether placed in intermediate storage or used to backfill previously mined out pits or strips in a one-time operation. Additional emissions from hauling and dumping overburden in spoils dumps are evaluated separately.

The stripping ratio R_S would be expected to vary from year to year, depending on such factors as the properties of the overburden or the depth of the overburden in the area being mined. The Black Butte plan, in fact, indicates a range of R_S from about 2 to more than 40 (at the end of the mine life). Annual data on overburden removal for North Block, Twin Creek, and South Haystack, however, were not made available in time to complete this phase of the study. Therefore, a lifetime average stripping ratio R_S was derived for each surface mine by dividing the total amount of overburden expected to be removed over the life of the mine by the total coal production.

The emission factor of 0.048 pounds per ton published by the EPA was based on a single mine in northwest Colorado, which agreed fairly closely with an independently derived factor for a lignite mine in North Dakota, where a dragline operation was employed. Dragline operation, especially where not properly controlled, has been observed to emit considerably more dust per unit overburden removed than a loading shovel/tractor type operation. Except for Black Butte, draglines are not deemed feasible for overburden removal at any of the proposed surface mines in the ES region. It is noted that the use of dragline at the North Dakota mine is probably counterbalanced to some degree by the

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*A swell factor of 15% is generally assumed for loose overburden.

higher moisture content of the overburden material in that area compared with southwest Wyoming. Overburden removal and coal production data are given in Table R4-37.

Overburden Spoils Dumps. In open pit coal mining, it is usually necessary to provide on-site spoils dumps during the life of the mine for a substantial portion of the overburden removed in the process of extracting the coal ore. From a fugitive dust perspective, interim or permanent storage of overburden and topsoil is similar to coal storage in that the principal transfer operations affecting emissions (assuming no controls) are the load-in and load-out activities. For coal, watering at transfer points can reduce emissions substantially. However, watering is normally unfeasible and ineffective for overburden transfer operations because of the large quantity that must be stored and the continuous exposure of dry subsurface material.

A second source of fugitive dust from overburden storage is wind erosion from the material placed in the dump. The EPA (1977, p. 2-44) states that "For most waste dumps, there are...probably only minimal additional emissions from wind erosion due to a lack of small particles on the surface." Although insufficient data exists, at present, to support or negate this statement for a spoils dump at a western coal mine, the effects of wind erosion from the undisturbed storage pile are considered to be adequately treated in the overall evaluation of wind erosion from exposed and partially reclaimed acreage at each mine.

A final activity associated with overburden storage piles; namely, the leveling and grading of the spoils dumps, also constitutes a potential source of particulate emissions. This activity involves one or more dozers and occurs daily.

Load-In and Load-Out of Stored Overburden. Emissions from overburden storage are probably the most difficult to quantify because of the lack of any published emission factors or test data. The EPA (1975) has published a technique for estimating the emissions from various activities associated with aggregate storage piles, including load-in and load-out. This technique consists of a simple equation (for each operation) relating total aggregate storage emissions to the inverse square of Thornwaite's precipitation-evaporation (PE) index. The equation has subsequently been modified (EPA 1977) to account for silt content. In addition, calibration factors (K-factors) have been introduced for specific leading equipment and material characteristics (K = 0.75 for low-medium volatility coal). Both the original and the modified versions were based on monitoring data from crushed rock, sand and gravel aggregate storage, in Cincinnati and Kansas City, where the PE index is about three times as high as southwest Wyoming. The EPA (1977) document cautions, in fact, that the formulas are to be regarded as preliminary and "subject to further refinement and change when test results become available." This same document (EPA 1977), in fact, treats overburden storage under the category of "Waste Disposal Sites" and notes the total lack of available information on emissions from aggregate storage of waste materials.

Because of the unavailability of an acceptable technique for estimating emissions associated with overburden storage activities, estimates were made based on the published EPA factors for coal storage (EPA 1977). Although this approach is subject to question because of the intrinsic differences between coal and overburden, the handling process should be similar for both materials at a given mine.

Load-in and load-out factors were estimated for the published EPA truck dumping and ore loading factors, respectively, for coal (EPA 1977). The equations for load-in and load-out follow.

Load-In

$$E_{OLI} \cong 0.5 * 10^{-3} F_{CTL} P'_{OB} \tag{R4-13a}$$

Load-Out

$$E_{OLO} \cong 0.5 * 10^{-3} F_{CTD} P''_{OB} \tag{R4-13b}$$

where

E_{OLI} and E_{OLO} is the total annual emissions (tons per year) from load-in and load-out of overburden at dump sites, respectively.

P'_{OB} is the amount of overburden placed in storage dumps (tons per year).

P''_{OB} is the amount of overburden removed from storage dumps and backfilled into mined out pits (tons per year).

F_{CTL} is the emission factor for truck loading (via loading shovel) of coal obtained from the EPA (1977) (0.10 pounds per ton coal).

F_{CTD} is the emission factor for truck dumping of coal obtained from the EPA (1977) (0.02 pounds per ton coal).

Other symbols were defined previously, following Equation (R4-11).

A comparison with the EPA factors for crushed rock, the only other extracted material for which both loading and dumping factors were provided, reveals that the sum of the two factors (truck loading plus truck dumping) is 0.09 for crushed rock, or about 25% lower. The coal factors were used mainly because it is assumed that the actual procedures used in loading and dumping of coal at surface mines would more nearly resemble those used for overburden material than the procedures employed at rock quarries or sand and gravel pits. Differences between overburden and coal removal procedures at the four surface mines are shown in Table R4-38.

TABLE R4-38

OVERBURDEN VERSUS COAL REMOVAL PROCEDURES

Mine	Primary Removal Procedures	
	Overburden	Coal
Black Butte	Dragline/Shovel	FEL*
North Block	Shovel	FEL
South Haystack	FEL or Backhoes	FEL
Twin Creek	Shovel	FEL

*FEL means front-end loader

Front-end loaders are routinely used in coal removal from surface mines and are believed to be somewhat less dust producing, under normal conditions, than shovels or backhoes (PEDCo 1976). However, the emission factor used here for truck loading (F_{CTL} = 0.1 pounds per ton) is twice as high as the figure estimated by Midwest Research Institute (MRI) for front-end loading of crushed rock. Therefore, the overall F_{OSL} factor appears to be conservative from an equipment utilization standpoint.

It is also noted that the sum of the approximated emission factors (0.12 pounds per ton) is 2.5 times as high as the published EPA factor for overburden removal, which is basically a combined load-in and load-out operation. The 0.12 pounds per ton combined factor is, however, much lower than the load-in and load-out components of the modified aggregate storage pile equation for crushed rock (0.62 pounds per ton assuming a silt content of 1.5%, PE = 33, and K-factors of 0.75). For reasons previously stated, however, use of this equation is deemed wholly inappropriate for overburden. Indeed, use of this latter factor would suggest that overburden storage emissions (including wind erosion) typically account for 85% or more of the total annual fugitive emissions from a surface coal mine. This is unrealistic and, in fact, completely inconsistent with actual observations at a number of western coal mines (PEDCo 1977).

Load-in and load-out operations at overburden dumps at each of the proposed surface mines are summarized in Table R4-39. The data reported in this table for Twin Creek, South Haystack, and Black Butte were obtained directly from mine personnel. For North Block, however, a detailed schedule of overburden deposition and retrieval has not been formulated. Therefore, a hypothetical schedule for North Block, based on South Haystack, was used; wherein it was assumed that:

- 20% of all overburden removed over the life of the mine is placed in spoils dumps in the first eight years (the initial 20% of the mine life) and
- 75% of all overburden placed in the dumps is backfilled into mined out pits in the last four years (the final 10% of the mine life).

Wind Erosion from Overburden Storage Piles. As previously stated, dust emissions from spoils dump wind erosion have never been quantified and, according to the most recent EPA document on the subject, are considered to be minor compared to load-in and load-out operations. For these reasons, and because spoils dumps are graded and reclaimed continuously, stored overburden emissions are treated as part of the overall contribution from the disturbed and exposed acreage to the annual mine emission burden (see "Wind Erosion from Exposed Land").

TABLE R4-39

APPROXIMATE VOLUME OF OVERBURDEN MATERIAL EXPECTED TO BE DEPOSITED AND RETRIEVED FROM SPOILS DUMPS AT SURFACE MINES*

	Annual Overburden Deposited or Retrieved from Dump (mm yd^3)					
	North Block**		Twin Creek[§]		South Haystack[§§]	
Year	Load-In	Load-Out	Load-In	Load-Out	Load-In	Load-Out
1979	–	–	–	–	15	–
1980	–	–	17	–	16	–
1981	3.3	–	14	–	16	–
1982	3.3	–	11	–	16	–
1983	3.3	–	3.5	–	16	–
1984	3.3	–	16	–	16	–
1985	3.3	–	12	–	–	–
1986	3.3	–	6	–	–	–
1987	3.3	–	2.5	–	–	–
1988	3.3	–	–	–	–	–
1989	–	–	–	–	–	–
1990	–	–	–	–	–	–
1991	–	–	–	–	–	–
1992	–	–	–	–	–	–
1993	–	–	–	4.5	–	–
1994	–	–	–	5	–	–
1995	–	–	–	–	–	–
1996	–	–	–[††]	–[††]	–	–
1997	–	–	–	19	–	–
1998	–	–			–	–
1999	–	–			–	–
2000	–	–			–[††]	–[††]
2001	–	–			–	25[†]
2002	–	–			–	24[†]
2003	–	–			–	24[†]
2016	–[††]	5.0[††]				
2017	–	5.0				

*Assumed to be negligible at Black Butte, where overburden removal be achieved primarily by dragline.

**Assumed schedule, based on Twin Creek plan.

[†] After end of mine life.

[††] End of mine life (EOML).

[§] Johnson 1978

[§§] Wilson 1978b

Grading Operations. At each surface mine, overburden and topsoil dump areas, as well as backfilled pits are continually graded and reclaimed. Grading is accomplished by D-9 dozers (which follow the various dragline, truck/shovel, and scraper operations). The dozer emissions are given by the formula

$$E_{DZ} = 0.5 * 10^{-3} F_{DZ} N_{DZH} \qquad \text{(R4-14)}$$

where

E_{DZ} is the annual emissions from grading (dozer) operations (tons per year)

F_{DZ} is the dozer emission factor (16 pounds per hour) (PEDCo 1976)

N_{DZH} is the number of dozer-hours per year

The number of dozers and periods of operation associated with the various activities at each surface mine are given in Table R4-40.

Miscellaneous Activities Associated with Overburden Storage. Other activities involved in the interim storage of overburden material with the potential for fugitive dust emissions include truck transit to spoils dumps, vehicular movement around storage piles, and topsoil storage. The term "truck transit emissions" refers to the situation where particles become dislodged by wind and truck motion from in-transit piles of overburden. According to the EPA (1977) and PEDCo (1976), such emissions are negligible when compared with emissions at actual transfer points (load-in and load-out). Another transit-related activity, wheel/surface interaction on haul roads, is not insignificant and is discussed later in "Haul Road and Access Road Traffic."

The degree of vehicular movement in and around the storage dump is difficult to predict and, in any case, is probably adequately accounted for in the overburden haul road emission estimates. It seems logical to assume that, unlike confined sand and gravel pits or stone quarries, spoils dumping represents a type of activity that would necessitate minimal vehicular movement in the dumping area.

Topsoil and subsoil storage and transport is considered to be incorporated in the overburden removal emissions E_{OBR} and in the wind erosion from unreclaimed land. According to a study performed for a lignite mine in North Dakota (PEDCo 1976), removal and interim storage of topsoil and subsoil was estimated to account for only about 6% of the total overburden removal contribution to fugitive dust. It is noted that the stored topsoil at the four southwest Wyoming surface mines would be seeded immediately to prevent erosion, so that after the first growing season, dust emissions from topsoil operation would probably be negligible.

TABLE R4-40

SUMMARY OF D-9 DOZER OPERATION SCHEDULES USED IN SPOILS DUMP RECLAMATION (ALL YEARS)

Surface Mine	No. of Dozers	Shifts per Week	Hours per Shift	Weeks per Year	Dozer Hours per Year
North Block*	2	10	7	50	7,000
Twin Creek**	2	15	7	48	10,080
South Haystack†	2	10	7	50	7,000
Black Butte††					
Dragline	2	20	7	50	14,000
Truck-and-Shovel	2	15	7	50	10,500
Scraper	1	10	7	50	3,500

*Assumed

**Johnson, 1978.

†Pachter, 1978.

††Wilson, 1978b.

Loading Coal. The formula for uncontrolled emissions associated with the loading of freshly mined coal onto haul trucks is given by

$$E_{CL} = 0.5 * 10^{-3} F_{CL} P_C \qquad \text{(R4-15)}$$

where

E_{CL} is the fugitive dust emissions from truck loading of coal (tons per year)

F_{CL} is the emission factor for truck loading of coal, assumed to be 0.1 pounds per ton uncontrolled (EPA 1977; PEDCo 1976)

P_C is the annual coal production (tons per year), Table R4-37

The factor of 0.1 pounds per ton is at the upper end of the range of values estimated for coal loading operations by a number of studies by the EPA (1977) and PEDCo (1976).

Dumping Coal. The formula for uncontrolled truck dumping emissions is given by

$$E_{CD} = 0.5 * 10^{-3} F_{CD} P_C \qquad \text{(R4-16)}$$

where

E_{CD} is the fugitive dust emissions from truck dumping of coal (tons per year)

F_{CD} is the EPA emission factor for truck dumping of coal (assumed to be 0.02 pounds per ton, uncontrolled) (EPA 1977; PEDCo 1976)

P_C is the annual coal production (tons per year), Table R4-37

Crushing and Screening. The formulas for uncontrolled primary crushing and secondary crushing/screening operations are given by

$$E_{C1} = 0.5 * 10^{-3} * f_{C1} F_{C1} P_C \text{ (primary crushing)} \qquad \text{(R4-17a)}$$

$$E_{C2} = 0.5 * 10^{-3} f_{C2} F_{C2} P_C \text{ (secondary crushing/screening)} \qquad \text{(R4-17b)}$$

where

E_{C1} is the fugitive dust emissions from primary crushing (tons per year)

E_{C2} is the fugitive dust emissions from secondary crushing/screening (tons per year)

F_{C1} is the EPA emission factor for primary crushing (0.02 pounds per ton, uncontrolled)

F_{C2} is the EPA emission factor for secondary crushing/screening (0.16 pounds per ton, uncontrolled)

P_C is the annual coal production (tons per year), Table R4-37

f_{C1} is the dust control factor for primary crushing controls

f_{C2} is the dust control factor for secondary crushing controls

The control factors depend on the type of dust controls proposed for each mine and are estimated from state-of-the-art estimates of control effectiveness (EPA 1977; PEDCo 1976). The specific controls assumed for each mine, along with estimated control factors, are given in Table R4-41. It is noted that the combined factor representing simultaneous implementation of two or more dust control measures is, in general, less than the arithmetic product of the factors (obtained from the literature) for the individual measures. This is so because certain measures, such as spraying, may be applied to only a portion of the total (uncontrolled) fugitive dust emissions, inasmuch as the primary measure (e.g., enclosing the crusher) has already reduced the emissions significantly.

Both primary and secondary crushing facilities are planned for each of the four surface mines. For the underground mines, it was assumed that any secondary crushing or screening would either remain underground or be omitted from the mine plan altogether. Hence, $E_{C2} = 0$ for the three underground mines. (Two of the underground mines, Winton and Reliance, are considered only in the cumulative impacts section of this report.)

Transferring Coal. The term "coal transfer operations" refers to the transport and conveyance of processed coal from the processing area to on-site storage. It does not include truck haulage of the raw ore to the central dump. The emissions from operations under this latter category are included in the (coal) truck loading, dumping, and haul road analyses.

The formula for emissions from coal transfer operations is given by

$$E_{CT} = 0.5 * 10^{-3} f_{CT} F_{CT} P_C \qquad \text{(R4-18)}$$

where

E_{CT} is the fugitive dust emissions from coal transfer and conveyance (tons per year)

$f_{CT} \simeq f_{WC} * f_{EC}$

f_{WC} is the control factor for watering or chemical stabilization (0.5)

f_{ec} is the control factor for enclosed conveyors (0.1)

f_{CT} is the EPA emission factor for coal transfer and conveyance (0.2 pounds per ton, uncontrolled)

P_C is the annual coal production (tons per year), Table R4-37

TABLE R4-41

SUMMARY OF DUST CONTROL MEASURES ANTICIPATED FOR PRIMARY AND SECONDARY COAL CRUSHING

Mine	Primary Crushing		Secondary Crushing	
	Controls Assumed	Estimated Efficiency* (%)	Controls Assumed	Estimated Efficiency* (%)
North Block	Spraying, DSH	95	Spraying, DSH	95
Twin Creek	Spraying, DSH	95	Enclosure, Spraying, DSH	98
South Haystack	Spraying, DSH	95	Enclosure, Spraying, DSH	98
Black Butte	Spraying, DSH	95	Enclosure, Spraying, DSH	98
Long Canyon	Spraying, DSH	95	NA	NA
Winton	Spraying, DSH	95	NA	NA
Reliance	Spraying, DSH	95	NA	NA

DSH means dust suppression hood.

NA means not applicable (no on-site secondary crushing).

*Control factor f_c = 1 - Efficiency/100

The control factors of 0.5 for watering or chemical stabilization and 0.1 for enclosed conveyers represent achievable reductions of 50% and 90%, respectively, for these control methods as estimated by field studies (EPA 1977; PEDCo 1976). These control factors were introduced in Equation (R4-18) because the five proposed mines and two projected mines expect to implement these techniques as part of their routine operations (Wilson 1978a; Christian 1978; Geslin 1978; Frank 1978).

Train Loading of Coal. The train loading operation is assumed to be similar to truck loading of coal, from a fugitive dust standpoint. Hence, the equation used to compute train loading emissions is

$$E_{TL} \simeq 0.5 * 10^{-3} f_{TL} F_{CL} P_C \qquad \text{(R4-19)}$$

where

E_{TL} is the annual emissions from train loading of coal (tons per year)

f_{TL} is the dust control factor for train loading controls

F_{CL} is the emission factor for truck loading of coal, assumed to be 0.1 pounds per ton (EPA 1977; PEDCo 1976) (see "Loading Coal")

P_C is the annual coal production (tons per year), Table R4-37.

It is assumed that the six mines where train transport to market points is involved will install telescoping chutes, dust supressors, and detergent spray systems. A combined control system of this type is estimated to be 98% effective (control factor = 0.02).

Storing Coal. The formula for fugitive emissions due to interim storage of deliverable coal is given by

$$E_{CS} = 0.5 * 10^{-3} f_{CS} F_{CS} P_C \qquad \text{(R4-20)}$$

where

E_{CS} is the annual emissions from in-place coal storage piles (tons per year)

f_{CS} is the dust control factor for coal storage control

F_{CS} is the emission factor for erosion from coal storage (0.054 pounds per ton) (EPA 1977)

P_C is the annual coal production (tons per year), Table R4-37.

Storage facilities envisioned for each of the seven mines are described in Table R4-42, along with the estimated control factor.

TABLE R4-42

STORAGE FACILITIES

Proposed Mines	Type of Storage Facility	Assumed Control Factor
North Block	None	-
Twin Creek	Silo (enclosed)	0.01
South Haystack	Silo (enclosed)	0.01
Black Butte	Silo (enclosed)	0.01
Long Canyon	Open	1.0
Projected Mines		
Winton	Conical (enclosed)	0.01
Reliance	Conical (enclosed)	0.01

Haul Road and Access Road Traffic. Truck haulage of coal and overburden and employee traffic over unpaved roads create fugitive dust by dislodging particles from the surface of the road that subsequently become re-entrained in the atmosphere.

Emissions from unpaved roads typically constitute 10 to 30% of the total fugitive dust emitted from both surface and underground coal mines, as evident from the results of the current investigation. Intuitively, unpaved road emissions depend on such variables as the silt and moisture content of the roadway surface; the amount of travel; and the speed, area of tire surface contact, and weight of the vehicles. On the basis of limited testing, the EPA and its contractors have developed a general equation for unpaved road emissions (EPA 1974, 1975):

$$F_{UR} = 0.6 * (0.81s) * \left(\frac{365-w}{365}\right) \left(\frac{S}{30}\right)^2 f_{UR} \quad (S \leq 30 \text{ mph}) \qquad \text{(R4-21)}$$

where

F_{UR} is the emission factor for unpaved roads (pounds per vehicle mile)

0.6 is the fraction (by weight) of emitted particles < 30 μm in diameter

f_{UR} is the control factor for surface treatment of unpaved roads

s is the silt content of roadway surface material

S is the mean vehicle speed control (miles per hour)

w is the number of days per year with snow cover or precipitation exceeding 0.01 inch

This equation is used in the present study to compute unpaved road emissions within and adjacent to the mine permit boundaries. The surface type, silt content, speed, number of snow/wet days, proposed controls, and resultant emission factors are given in Table R4-43 for the seven mines analyzed and for the three road categories: coal haul roads, overburden haul roads, and employee access roads.

The contribution of unpaved road emissions is computed from the following formulas.

Coal Haul Road Traffic.

$$E_{URC} = 10^{-3} F_{URC} (P_C/T_{CC}) * D_C \qquad \text{(R4-22)}$$

where

E_{URC} is the annual emissions from coal haul roads (tons per year)

TABLE R4-43

SUMMARY OF INPUT PARAMETERS USED TO DETERMINE UNPAVED ROADWAY FUGITIVE DUST EMISSION FACTORS FOR ES REGION MINES

Mine	Roadway Surface Type/ Assumed Silt Content(%)		Proposed Controls (Control Factor)		Estimated Speed (mph)		No. Wet/ Snow Cover Days per Year	Emission Factor (pounds per vehicle mile)	
	Haul	Access	Haul	Access	Haul	Access		Haul	Access
North Block	Gravel/12	Gravel/12	Watering (0.5)	Chemical or Water Spray (0.5)	15	30	153	3.75	3.38
Twin Creek	Gravel/12	Gravel/12	Watering (0.5)	Oil (0.15)	15	30	153	2.11	3.38
South Haystack	Gravel/12	Gravel/12	Watering (0.5)	Oil (0.15)	15	30	153	2.11	3.38
Black Butte	Gravel/12	Gravel/12	Watering (0.5)	Oil (0.15)	18	20	114	3.53	1.79
Long Canyon	NA	Gravel/12	NA	Oil (0.15)	NA	30	114	NA	4.02
Reliance	NA	Gravel/12 or Mercadam	NA	(0.1)*	NA	30	114	NA	4.02
Winton	NA	Gravel/12 or Mercadam	NA	(0.1)*	NA	30	114	NA	4.02

*Assumed for mercadam-like surface.

F_{URC} is the emission factor (F_{UR}) for coal haul roads (pounds per vehicle mile), Table R4-43

P_C is the annual coal production (tons per year)

T_{CC} is the average tonnage capacity of coal trucks

D_C is the length of coal haul roads (one-way haulage distance in miles)

Overburden Haul Road Traffic.

$$E_{URO} = 10^{-3} F_{URO} \left[\frac{P_{OBS}}{T_{OBC}} \right] * D_{OB} \qquad \text{(R4-23)}$$

where

E_{URO} is the annual emissions from overburden haul roads (tons per year)

F_{URO} is the emission factor (F_{UR}) for overburden haul roads (pounds per vehicle mile), Table R4-43

P_{OBS} is the annual amount of overburden placed in storage dumps (tons per year). $P_{OBS} = P_{OB}'$ or P_{OB}'' depending on whether overburden is being placed into dumps or taken out [see Equation (R4-13)]

T_{OBC} is the average tonnage capacity of overburden haul trucks

D_{OB} is the length of overburden haul roads (one-way haulage distance in miles)

Employee Access Road Traffic.

$$E_{URA} = 10^{-3} F_{URA} N_E N_{WD} D_A / N_{EV} \qquad \text{(R4-24)}$$

where

E_{URA} is the annual emissions from employee access roads (tons per year)

F_{URA} is the emission factor (F_{UR}) for employee access roads (pounds per vehicle mile), Table R4-43

N_E is the number of employees

N_{WD} is the number of work-days per year (assumed to be 52 x 5 = 260 for all seven mines)

N_{EV} is the number of employees per vehicle, or vehicle occupancy rate, (assumed to be 3.0 for all mines*)

D_A is the length of employee access road (one-way mileage from the junction of the nearest public road to the employee parking area)

Parameters and resultant emissions for each mine are presented in Table R4-44

Haul Road Maintenance. Aside from the normal truck and automobile traffic on unpaved roads, equipment used to maintain the haul roads constitutes an additional source of unpaved road emissions. These activities are somewhat similar to spoils dump grading, from a fugitive dust standpoint. Emissions from maintenance operations are given by

$$E_{MUR} = 0.5 * 10^{-3} F_{GR} N_{GRH} \qquad \text{(R4-25)}$$

where

E_{MUR} is the annual emissions from maintenance operations (tons per year)

F_{GR} is the emission factor for grader operations (taken to be 16 pounds per hour)

N_{GRH} is the number of grader-hours per year required for haul road maintenance

For all four surface mines, it was assumed that routine maintenance operations would involve two separate "blades" or patrols, each working 10 shifts per week, 7 hours per shift, and 50 weeks per year. Thus, for all surface mines

$$N_{GRH} = 2 \times 10 \times 7 \times 50 = 7{,}000 \text{ hours per year}$$

Thus,

$$E_{MUR} = 56 \text{ tons per year for all four surface mines.}$$

Wind Erosion from Disturbed and Exposed Land. Wind erosion is the general term applied to all processes where the soil particles become disturbed by the ambient wind. The type of motion initiated falls into one of three basic categories:

- surface creep (rolling along the ground), involving particles ranging from 0.5 to 1.0 mm in diameter;

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*Wilson 1978b; Frank 1978.

TABLE R4-44

SUMMARY OF MINE SPECIFIC INPUT PARAMETERS NECESSARY TO DETERMINE UNPAVED ROAD EMISSIONS

Mine	Truck Capacity (tons)		One-Way Access Road Length (miles)	One-Way Haulage Distance (Miles)								Number of Employees			
				Coal*				Overburden*							
	Coal	Overburden		1980	1985	1990	EOML	1980	1985	1990	EOML	1980	1985	1990	EOML
North Block	100	120	4.5	–	6.0	6.0	6.0	0.5†	0.5†	0.5†	0.5†	50	200	200	200
Twin Creek	50	120	0.08	2.0	2.0	3.0	3.0	1.6	1.4	1.0	1.0	400	300	300	300
South Haystack	85**	160**	2.79	0.83	0.83	0.83	0.83	3.6	3.6	3.6	3.6	310	260	260	260
Black Butte	120	NA	5.0	4.5	4.5	4.5	4.5	NA	NA	NA	NA	371	320	320	320
Long Canyon	NA	NA	6.0	NA	NA	NA	NA	NA	NA	NA	NA	225	400	400	400
Winton	NA	NA	3.7	–	NA	NA	NA	–	NA	NA	NA	–	270	270	270
Reliance	NA	NA	2.0	–	NA	NA	NA	–	NA	NA	NA	–	125	125	125

EOML means end of mine life.

NA means not applicable.

*Assumed constant for all years (even though this is not strictly true), unless more specific information was available.

**Modeled for "Year 2" in mine plan and assumed for all years.

†Assumed, from visual inspection of plot plan.

- saltation (jumping within a confined area); generally affecting particles 0.1 to 0.5 mm in diameter; and
- suspension, involving particles smaller than 100 μm (0.1 mm).

From the standpoint of particulate air quality, only those particles that remain more or less permanently suspended (<30 μm, in general) are of interest. For most soil types, it is assumed that only 2.5% of the total soil eroded (i.e., 2.5% of all particles that are dislodged from their in situ position by the ambient wind) become permanently suspended.

Wind erosion is a highly complex function of several interacting variables, including soil characteristics (erodability), climatic conditions (characteristic wind speeds, precipitation, and evaporation), vegetative cover (flat residue or plantings), surface roughness, and field barrier effects. A nonlinear technique for estimating wind erosion and incorporating all of these factors was proposed by Woodruff and Siddoway (1965). The EPA (1974) presents a linearized version of the equation, given by

$$F_{WE} = aIKCL'V' \qquad \text{(R4-26)}$$

where

F_{WE} is particulate emissions area source density (emission factor - tons per acre per year) from wind erosion

a is 0.025 (fraction of disturbed soil below 30 μm in size)

I is soil erodability in tons per acre per year (a function of the percentage of dry aggregates exceeding 0.84 mm in diameter)

K is surface roughness factor (dimensionless)

C is climatic factor (dimensionless)

L' is unsheltered field width factor (dimensionless)

V' is vegetative cover factor (dimensionless)

The climatic factor C is given by the formula

$$C = 0.345 \frac{u^3}{(PE)^2} \qquad \text{(R4-27)}$$

where

u is the mean annual wind velocity (mph), measured at a standard height of 30 feet

PE is the Thorntwaite's precipitation-evaporation index

The factors K, C, L', and V' represent adjustments to a worst-case situation of an infinitely long, unsheltered, bare flat field in a climate similar to extreme western Kansas (C = 1.0). Presumably, all of these factors can be reduced by implementing appropriate soil conservation measures, except the climatic factor. Values of I are given by the EPA (1974) for common soil textural classes.

In the present investigation, surface roughness and sheltering effects are ignored for conservatism (K = 1.0, L' = 1.0). Climatic factors were based on a regionwide PE index of 33 (EPA 1977, 1974; PEDCO 1976) and mean wind speeds obtained at Rock Springs Airport (Sweetwater County) and Fort Bridger (Lincoln and Uinta Counties). For the vegetative cover factor, it was assumed (again, for conservatism) that planting would begin in the fall, and that this would reduce erosion by 10% for the analysis year. Thereafter, it was assumed that erosion would drop off linearly to a level that would exist at the site if left undisturbed (i.e., the ambient level for the no-action scenario at that particular site). Thus, the wind erosion emissions for Year Y_c ("year of interest" or "current year") are estimated by the equation

$$E_{WE}(Y_c) = [0.9A(Y_c) + 0.6A(Y_c-1) + 0.3A(Y_c-2)]*F_{WE} \quad \text{(R4-28)}$$

where

E_{WE} is the annual wind erosion emissions in Year Y_c (tons per year)
$A(Y_c)$ is the number of acres unreclaimed in Year Y_c
$A(Y_c-1)$ is the number of acres unreclaimed in Year Y_c-1
$A(Y_c-2)$ is the number of acres unreclaimed in Year Y_c-2

Equation (R4-28) implies that a two-year reclamation delay (not counting the current year) is assumed. The second and third terms in the square brackets represent the contribution to the emissions of "reclamation delay factor." It is important to note that each A(Y) is the number of acres left exposed (incompletely reclaimed) in Year Y and not the "acres disturbed." The unreclaimed area is computed from the mine reclamation schedule by subtracting (for Year Y) the accumulated acres reclaimed from the accumulated acres disturbed. Actual values turn out to be significantly greater than the figure for acres disturbed in Year Y, because land area taken out of the system for such functions as spoils dumps, haul roads, parking, and shop areas, etc. are included in the A(Y).

Acreages and parameters used in the linearized wind erosion equation for the seven mines analyzed are given in Table R4-45.

TABL 4-45

MINE SPECIFIC PARAMETERS AND ACREAGE FIGURES FOR THE EVALUATION OF FUGITIVE DUST EMISSIONS FROM WIND EROSION

	North Block	Twin Creek	South Haystack	Block Butte	Long Canyon	Winton	Reliance
Soil Type	CL	CL	CL	SL	SL	SL	SL
Erodability (I)*	47	47	47	86	86	86	86
Climatic Factor	1.07	1.07	1.07	0.42	0.42	0.42	0.42
Unreclaimed Acreage**							
1980	216	642	593	1,058	150	-	-
1979	-	-	150	268	-	-	-
1978	-	-	-	73	-	-	-
1985	211	1,455	446	1,901	150	40	40
1984	50	42	60	736	-	-	-
1983	55	39	60	666	-	-	-
1990	211	1,183	551	1,561	150	40	40
1989	50	70	60	794	-	-	-
1988	50	170	60	641	-	-	-
EOML	211	161	437	1,374	150	40	40
EOML - 1	50	202	103	454	-	-	-
EOML - 2	50	205	100	374	-	-	-

EOML means end of mine life.

CL means clay loam.

SL means sandy loam.

* Tons per acres per year.

** Acreage subject to a degree of wind erosion higher than what would occur if the land were left undisturbed.

Procedures for Estimating Meteorological Parameters Used in the Emissions Analyses

The contents of this section include a brief description of meteorological and/or climatological parameters used in the emissions inventory and modeling phase of the impact analysis.

Climatic Factor. The U.S. Department of Agriculture has developed an equation for estimating fugitive dust emissions from agricultural fields. For the present study, a simplified format of the equation has been incorporated following the recommendation of the EPA (1974). One component of this equation includes a climatic factor, C, a dimensionless parameter indicating that the rate of soil movement by wind varies directly with the cube of the wind velocity and inversely with the square of the soil moisture. The equation for calculation of the climatic factor is:

$$C = 0.345 \frac{w^3}{(PE)^2} \qquad \text{(R4-29)}$$

where

w is the mean annual wind velocity

PE is Thornthwaite's precipitation-evaporation index (Thornthwaite 1931)

Since available evaporation data are generally insufficient, Thornthwaite developed a formula to express his PE index for average precipitation and temperature. Thornthwaite's equation incorporates these data as follows:

$$PE = \sum_{n=1}^{12} 115 \left(\frac{P_n}{T_n - 10}\right)^{\frac{10}{9}} \qquad \text{(R4-30)}$$

where

P is the mean monthly precipitation in inches

T is the mean monthly temperature in °F

A PE index of 33 was used for southwest ES region (EPA 1975). The mean wind speeds at Rock Springs and Fort Bridger are 10.5 and 15.1 mph, respectively. Consequently, from Equation R4-29, climatic factors of 0.37 and 1.09 were evaluated for Sweetwater and Uinta Counties, respectively.

Percentage of Days per Year with Dry/Unfrozen Surface. The EPA has developed an equation for estimating fugitive dust emissions from unpaved roads. This equation was used to estimate the fugitive dust impact of both the existing unpaved road conditions and the impact of proposed mine-related vehicular movements on unpaved roads. One component of this equation is $\frac{365-W}{365}$ where W equals the number of days of wet/frozen surface and $\frac{365-W}{365}$ yields the percentage of the days per year with dry/unfrozen surface.

Sweetwater County. For Sweetwater County, the number of days with dry-unfrozen surface was developed from climatological data collected at Rock Springs Airport. The total of days with snow-cover (defined as one inch or more on the surface) was estimated from 1974 and 1975 climatological summaries prepared by the U.S. Department of Commerce. An average of 67 days per year was evaluated.

Other factors to be considered in the limitation of the flux of surface dust would be the number of days the ground is frozen (EPA 1974), and the number of days when a given amount of rain, e.g., 0.01 inch (EPA 1974), is exceeded.

However, the number of days the ground is frozen is not a figure easily derived, since a soil temperature less than 32°F is a necessary but not sufficient condition to cause frozen ground. Therefore, frozen ground days were considered to coincide with the period of snow cover days. Moreover, for conservatism, only those days with greater than or equal to 0.01 inches of precipitation during the warmest months (April to October) were considered to eliminate possible overlap with snow cover days. From a 34-year period of record (Department of Commerce 1965), Rock Springs receives 0.01 inches or more on 47 days over the seven-month period. Consequently, the cumulative effect of snow cover plus rainfall (W) is estimated to be 114 days per year. Taking the complement of this annual value yields 250 days of dry/unfrozen surfaces in the Sweetwater County area. Therefore, the equation $\frac{365-W}{365}$ equals 0.69 for Sweetwater County.

Uinta and Lincoln Counties. The total number of days with snow cover was not available for any stations within Uinta and Lincoln Counties. Since data had been compiled for Carbon County, and mean snowfall totals were found to be comparable, its data for snow cover were assumed applicable to Uinta and Lincoln (106 days per year). In addition, the number of days with frozen ground were assumed to coincide with snow cover days.

Those days with greater than or equal to 0.01 inches of precipitation during the warmest months (April to October) were considered wet surface days. From the 34-year period of record (Wyoming Natural Resource Board 1966), Rock Springs located in Sweetwater County, receives 0.01 inches or more of rain on 47 days per year. Consequently, the total of snow cover plus rainfall (W) is estimated to be 153 days per year, and the number of dry/unfrozen days is estimated to be 212 days per year.

Therefore, the equation $\frac{365-W}{365}$ equals 0.58 for these counties.

Results of Emissions Analysis

Contributions to the annual particulate emissions burden from the various fugitive dust sources at each of the five proposed mines are given in Tables R4-46 to R4-50. Results for the two projected private mines are provided in Tables R4-51 and R4-52. Although these emission rates are given as yearly averages, all activities, are not continuous. As such, they are approximations of the complex interaction of variables that affects pollutant emissions. From the tables, the following observations are apparent.

- In general, wind erosion from unreclaimed land constitutes the most significant single source of fugitive dust from the surface mines, accounting for 20 to 50% of the total. These figures, however, are based on the assumption that planting would begin in the fall, that surface roughness and sheltering effects are negligible and that mulching and planting are performed in a one-step operation.
- Overburden removal and storage operations appear to be the most important sources of emissions except for wind erosion, accounting for about 25 to 40% of total fugitive emissions. It is noted that overburden removal constitutes 68% of the total emissions for Black Butte in the final year of coal mining because of the inordinately large amount of overburden material (200 million tons) that must be displaced.
- Emissions from haul and access road traffic at the surface mines range from 10% of the total at Twin Creek and Black Butte to about 30% at South Haystack for those years when overburden haulage would be occurring. Unpaved road emissions would only be about 3% of the total for both South Haystack and Twin Creek during those years when overburden would not be hauled.
- Emissions from coal handling and storage account for only about 2% of the total particulate emissions at the surface mines and 10 to 15% of the total for the underground mines.

TABLE R4-46

SUMMARY OF PARTICULATE EMISSIONS FROM NORTH BLOCK MINE

Source	Annual Particulate Emissions (tons per year)			
	1980	1985	1990	EOML
Overburden Removal*	-	133	133	133
Spoils Dump Emissions				
Load-In	-	50	-	-
Load-Out	-	-	-	375
Grading	56**	50	56	56
Unpaved Road Emissions				
Employee Access	33	132	132	132
Coal Haul Roads	-	158	158	158
Overburden Haul Roads	-	40	-	60
Haul Road Repair	-	56	56	56
Coal Handling Emissions				
Ore Loading	-	70	70	70
Truck Dumping	-	14	14	14
Conveying	-	7	7	7
Crushing (Primary)	-	0.7	0.7	0.7
Crushing (Secondary)	-	5.6	5.6	5.6
Wind erosion of unreclaimed land	245	299	298	298
TOTAL ANNUAL EMISSIONS	334	1,021	930	1,356

EOML means end of mine life.

*Associated directly with extraction of coal ore.

**Dozer operations associated with initial construction.

-Operation not active in this year.

TABLE R4-47

SUMMARY OF PARTICULATE EMISSIONS FROM TWIN CREEK MINE

Source	Annual Particulate Emissions (tons per year)			
	1980	1985	1990	EOML
Overburden Removal*	648	648	648	648
Spoils Dump Emissions				
Load-In	255	180	-	-
Load-Out	-	-	-	-
Grading	81	81	81	81
Unpaved Road Emissions				
Employee Access	1.4	1.1	1.1	1.1
Coal Haul Roads	105	105	158	158
Overburden Haul Roads	359	222	-	-
Haul Road Repair	56	56	56	56
Coal Handling Emissions				
Ore Loading	125	125	125	125
Truck Dumping	25	25	25	25
Conveying	12.5	12.5	12.5	12.5
Crushing (Primary)	1.2	1.2	1.2	1.2
Crushing (Secondary)	4	4	4	4
Storage	0.7	0.7	0.7	0.7
Train Loading	2.5	2.5	2.5	2.5
Wind erosion of unreclaimed land	729	1,702	1,434	415
TOTAL ANNUAL EMISSIONS	2,405	3,166	2,549	1,530

EOML means end of mine life.

*Associated directly with extraction of coal ore.

-Operation not active in this year.

TABLE R4-48

SUMMARY OF PARTICULATE EMISSIONS FROM SOUTH HAYSTACK MINE

Source	Annual Fugitive Dust Emissions (tons per year)			
	1980	1985	1990	EOML
Overburden Removal*	382	763	763	638
Spoils Dump Emissions				
Load-In	240	-	-	-
Load-Out	-	-	-	-
Grading	56	56	56	56
Unpaved Road Emissions				
Employee Access	38	32	32	32
Coal Haul Roads	15.5	31	31	26
Overburden Haul Roads	570	-	-	-
Haul Road Repair	56	56	56	56
Coal Handling Emissions				
Ore Loading	75	150	150	125
Truck Dumping	15	30	30	25
Conveying	7.5	15	15	12.5
Crushing (Primary)	0.8	1.5	1.5	1.2
Crushing (Secondary)	2.4	4.8	4.8	4.0
Storage	0.4	0.8	0.8	0.7
Train Loading	1.5	3.0	3.0	2.5
Wind erosion of unreclaimed land	624	453	550	486
TOTAL ANNUAL EMISSIONS	2,084	1,596	1,693	1,466

EOML means end of mine life.

*Associated directly with extraction of coal ore.

-Operation not active in this year.

TABLE R4-49

SUMMARY OF PARTICULATE EMISSIONS FROM BLACK BUTTE MINE

Source	Annual Particulate Emissions (tons per year)			
	1980	1985	1990	EOML
Overburden Removal*	1,121	1,435	960	4,800
Spoils Dump Emissions				
Grading	224	224	224	224
Unpaved Road Emissions				
Employee Access	43	37	37	37
Coal Haul Roads	357	437	417	219
Haul Road Repair	56	56	56	56
Coal Handling Emissions				
Ore Loading	270	330	315	165
Truck Dumping	54	66	63	33
Conveying	27	33	32	16
Crushing (Primary)	2.7	3.3	3.2	1.6
Crushing (Secondary)	8.6	10.6	10.1	5.3
Storage	1.5	1.8	1.7	0.9
Train Loading	5.4	6.6	6.3	3.4
Wind erosion of unreclaimed land	1,020	2,111	1,861	1,467
TOTAL ANNUAL EMISSIONS	3,190	4,751	3,986	7,028

EOML means end of mine life.

*Associated directly with extraction of coal ore.

TABLE R4-50

SUMMARY OF PARTICULATE EMISSIONS FROM LONG CANYON MINE

Source	Annual Particulate Emissions (tons per year)			
	1980	1985	1990	EOML
Unpaved Road Emissions				
Employee Access	70.5	125	125	125
Coal Handling Emissions				
Ore Loading	25	100	100	100
Truck Dumping	5	20	20	20
Conveying	2.5	10	10	10
Crushing (Primary)	0.2	1.0	1.0	1.0
Storage*	3.4	13.5	13.5	13.5
Train Loading	0.5	2.0	2.0	2.0
Wind erosion of unreclaimed land	135	135	135	135
TOTAL ANNUAL EMISSIONS	242	406	406	406

EOML means end of mine life.

*Ninety days of open storage is assumed.

TABLE R4-51

SUMMARY OF PARTICULATE EMISSIONS FROM WINTON MINE

Source	Annual Particulate Emissions (tons per year)		
	1985	1990	EOML
Unpaved Road Emissions			
Employee Access	34.8	34.8	34.8
Coal Handling Emissions			
Ore Loading	100	100	100
Truck Dumping	20	20	20
Conveying	10	10	10
Crushing (Primary)	1.0	1.0	1.0
Storage	0.5	0.5	0.5
Train Loading	2	2	2
Wind erosion of unreclaimed land	36	36	36
TOTAL ANNUAL EMISSIONS	204	204	204

EOML means end of mine life.

TABLE R4-52

SUMMARY OF PARTICULATE EMISSIONS FROM RELIANCE MINE

Source	Annual Particulate Emissions (tons per year)		
	1985	1990	EOML
Unpaved Road Emissions			
Employee Access	8.7	8.7	8.7
Coal Handling Emissions			
Ore Loading	25	25	25
Truck Dumping	5	5	5
Conveying	2.5	2.5	2.5
Crushing (Primary)	0.2	0.2	0.2
Storage	0.1	0.5	0.5
Train Loading	0.5	0.5	0.5
Wind erosion of unreclaimed land	36	36	36
TOTAL ANNUAL EMISSIONS	78	78	78

EOML means end of mine life.

- Because overburden removal and truck haulage is not involved in the underground mines, wind erosion, coal handling, and access roads are predicted to account for a significantly higher *percentage* of the total emissions at these mines compared with the surface mines. Fugitive emissions from underground mines, however, are typically an order of magnitude (or more) *lower* than surface mine emissions.

Reliability of Results

At the onset of this discussion, it was stressed that the state-of-the-art of fugitive dust emission factor analysis for coal mines, as well as the accuracy of input data, is extremely limited; and, therefore, the results obtained in this study would be useful only from an order of magnitude, or comparative, perspective. Emission factors used in this investigation for most coal mining activities were obtained from basis documents that estimated these factors by applying professional judgment to results obtained from air quality sampling in the vicinity of nonmining activities. Another major source of inaccuracy arises from applying regional climatic or soil data to a specific location. Thus, although every attempt has been made to use the meager information available in a realistically conservative fashion, it is extremely unlikely that the results of this investigation can be used to assess the impact of a specific coal mine from the standpoint of compliance or noncompliance with ambient standards.

To underscore the limitations of the state-of-the-art, two tables have been prepared. The first (Table R4-53) summarizes the reliability ratings, bases of estimates, and principal sources of error for the various activity emission factors used in arriving at the mine-specific emission burdens in Tables R4-45 through R4-52. Because of the influence and wide variability of local climatic characteristics, the location of each study area for which these emission factors were originally developed is also provided. The second table (R4-54) gives the range of factors obtained from recent coal mine studies.

Reliability ratings for fugitive emission factors have been defined by the U.S. EPA as follows:

A = Excellent

B = Good

C = Average (Supportable by multiple test data)

D = Below Average (Supportable by limited test data at coal mines and engineering judgment)

E = Poor (Supportable by best engineering judgment, involving visual observation and judgmental adjustments to results of emissions tests conducted at nonmining sources)

TABLE R4-53

RANGE OF FUGITIVE EMISSION FACTORS OBTAINED FROM COAL MINE RELATED STUDIES

Source Category	PEDCo Units	Values from PEDCo (1977) Range	Mine	Range of Values Estimated from Previous Studies[Δ]
Overburden Removal		-	-	0.048-0.1 lb/ton material
Dragline	lb/yd^3	0.0056-0.053	0.053	0.048-0.1 lb/ton material
Truck/Shovel	lb/ton	*	**	-
Blasting	lb/blast	14.2-85.3[†]	**	-
Spoils Dumps				
Topsoil	lb/yd^3	*	**	
Grading	lb/yd^3	*	**	
Unpaved Roads				
Haul Roads[††]	lb/VMT	3.3-13.6[ΔΔ]	13.6	ΔΔ
Coal Handling				
Ore Loading	lb/ton	0.002-0.014	0.007	0.02-0.1 lb/ton
Truck Dumping[§]	lb/ton	0.005-0.027	0.020	
Train Loading	lb/ton	*	**	
Wind Erosion	tons/acre/yr	§§	**	Depends on climate and soil factors

*An emission factor for this activity was developed for only a single mine.

**No emission factor was developed for the southwest Wyoming mine.

[†] Based on only two mines.

[††] Watering control applied.

[§] Bottom dump.

[§§] No emission factor for wind erosion could be developed at any of the mines.

[Δ] Not based on coal mine sampling.

[ΔΔ] Range depends on vehicle speed and wet/snow cover days, etc.

TABLE R4-54

RELIABILITY RATINGS, BASIS OF ESTIMATES, AND PRINCIPAL SOURCES OF ERROR IN EVALUATING FUGITIVE DUST EMISSIONS

Source Category	Emission Factor Reliability Rating*	Basis of EPA Estimate	Location of Principal Coal Mine Study	Major Sources of Error
Overburden removal	E**-F[†]	Adjustments to aggregate handling and storage and heavy construction factors.	Northwest Colorado	Vertical amplitude of dragline cycle, climatic factors.
Spoils dumps				
Topsoil	E	Aggregate storage equations.	North Dakota (lignite)	
Load-in	F	Aggregate storage equations.[††]		Moisture and silt content of overburden, PE index.
Load-out	F	Aggregate storage equations.[††]		Moisture and silt content of overburden, PE index.
Grading	E	Estimated from construction factors.	North Dakota (lignite)	Silt content, PE index, number and types of equipment.
Unpaved roads				
Employee access	C[§]	Rural gravel roads in Kansas.		Climatic factor, speed.
Haul roads	C-E[§]	Rural gravel roads in Kansas.		Truck correction factor, character of roadway surface, climatic factor, speed.
Road repair	E-F	Estimated from construction factors and unpaved road formulas.		
Coal handling				
Ore loading	E	Adjustments to crushed or rock factors to account for higher moisture and fewer fines.	Western U.S.	Moisture and silt content of coal, number and types of equipment.
Truck dumping	E	0.5* (crushed rock factor), based on the higher moisture content of coal.	North Dakota/Montana	Moisture and silt content of coal, type of truck.
Conveying	E	Hybrid of processing emissions estimated for various studies.	Northwest Colorado	Effectiveness of controls.
Crushing	E	Δ	North Dakota (lignite)	Effectiveness of controls.
Coal storage	D	Sampling at storage piles.	Δ	Effectiveness of controls, climatic factor.
Train loading	E-F	Truck dumping factor used in present investigation.		Moisture and silt content of coal.
Wind erosion of unreclaimed land	§§	Most wind erosion base data obtained from field studies in western Kansas.		Soil type, topography, surface roughness, type of vegetation, climatic factor, drop-off rate assumed due to reclamation.

[*] See text for definition of ratings.

** For dragline

[†] For truck/shovel.

[††] Coal factors applied to present investigation

[§] Test results generally agree with formulas to within ±10%. Main source of error is in assumption of mine specific input variables.

[§§] The wind erosion equation is generally accurate to within ±5%. However, errors in input (such as the climatic factor) can yield inaccuracies in the results of 100% or more.

[Δ] Unavailable from the literature.

In addition to the above, an "F" rating has been included for those source categories (activities) where no emission factors are available from published data (including EPA documents), requiring that an existing (published) factor for a "similar" activity be used. Thus, for example, an "F" rating was assigned to the emission factor for load-in and load-out of overburden at spoils dumps, inasmuch as the truck dumping and loading of coal were considered as substitutes for these activities. EPA factors for truck dumping and loading of coal, however, were not based on any sampling at a coal mine and are, themselves, assigned a reliability rating of "E." It is noted that both "E" and "F" represent essentially the same level of reliability, the basic distinction being direct application of the published factors versus the use of a different activity or material as a surrogate.

From Table R4-53, it is observed that all but three or four of the activity emission factors fall into the "E" or "F" reliability rating category. Even those factors that were derived or calibrated from sampling data may be less reliable when applied to a given mine than implied by the rating. The uncertainties in the input data (in particular, climate and soil factors) introduce further inaccuracies in the resultant emission estimates. Thus, for example, the accuracy of the estimated contribution from wind erosion depends on the validity of extrapolating test results in western Kansas to southwestern Wyoming as well as the ability of a region-wide PE index to represent the situation at a given mine.

As previously stated, none of the factors presented in the basis documents used in this study were derived from sampling at coal mines except for the coal storage factor. The recent PEDCo Draft Report (1977) presented emission factors that were based on sampling at five western surface mines, including one in southwestern Wyoming. Because this document had not undergone a full review at the onset of the present investigation, these more recent factors were not used to evaluate ES region coal mine emissions. However, to provide some indication of the range of values that might be expected within a particular geographical region of the United States, the highest and lowest values (range) obtained among the five western mines are reported in Table R4-54, along with the actual factor for the southwestern Wyoming mine. Only those activities for which emission factors could be developed are included. In a limited number of instances, a range of factors is also available from the earlier studies (that did not involve coal mine sampling) on which the EPA factors are based (EPA 1977). These ranges are also given in Table R4-54, where available.

Regional Impact on Air Quality

Emission rates associated with the mines considered in the most probable level of mining activity are summarized in Table R4-53. As discussed previously, these rates represent annual averages, although all activities are not continuous. As such, they are realistic approximations of the complex interaction of variables that affect pollutant emissions. Use of these emission rates in model predictions is discussed in the following sections.

Modeling Techniques

Diffusion modeling is a mathematical tool used in the field of air pollution meteorology to simulate the various processes that affect airborne effluents from a pollutant source or group of sources, from the time that an effluent leaves the source until the time it arrives at any one of several receptor sites. A model takes into account physical atmospheric processes that transport and diffuse an effluent. By use of a computer, one can calculate the impact of various meteorological conditions and source characteristics upon ground-level pollutant concentrations.

Once a pollutant source at or near the ground emits an effluent into the atmosphere, meteorological conditions affect both the transport and diffusion of the effluent. It is convenient, for the purposes of discussion, to refer to the volume of air containing any of the substance emitted from any continuous air pollution source as a "plume." Point, line, and area sources emit "plumes" of very different shapes and sizes, but the atmospheric processes that affect the plume apply to each in the same manner. Plume transport is determined largely by wind speed and direction. A plume will follow the trajectory of the local wind. An increase in wind speed tends to stretch a plume in the downwind direction, thus decreasing its concentration, and a change in wind direction can act in a similar manner to spread a plume through a larger volume of air and decrease the concentration over time at any one point.

A wind speed class is defined by the range of wind speeds likely to accompany a particular weather condition or stability class. For example, in an unstable weather condition, wind speeds are likely to range from 2 to 12 mph. It is physically impossible to have an unstable condition with winds of 50 mph. During neutral stability, however, winds up to 35 mph would be reasonable. Thus, when a model considers neutral weather conditions, the appropriate wind speed classes will have winds from 4 to 35 mph. For purposes of modeling, sixteen wind directions are defined by dividing a 360° circle into sixteen sectors, each sector incorporating a 22.5° segment of the circle.

Meteorological data for use in modeling were obtained from observations taken at Rock Springs and Fort Bridger. The Rock Springs data were assumed to be representative of the Long Canyon, and Black Butte project areas. The Fort Bridger data were assumed to be representative of the North Block, South Haystack, and Twin Creek project areas. Observations of wind speed, wind direction, and stability were recorded for five years. Stability wind roses were generated from these observations and used in this study for calculations of annual average concentrations. A stability wind rose delineates the joint frequency distribution of each wind speed class, wind direction, and atmospheric stability.

A significant meteorological factor in 24-hour average concentrations, which can lead to high daily averages, is the persistence of one wind direction, causing continuous impact at a particular receptor. Persistence data were obtained for the above areas and used in determining worst-case meteorological conditions for modeling 24-hour impact.

Modeling Long-Term Concentrations. The ERT air quality model (ERTAQ) was used to model long-term impact of all emissions shown in Tables R4-55, 56, and 57. The emissions from the various sources at each mine were added to represent a single source originating across the entire mining area. For analytical purposes, each mine was modeled as an area source. Because of the wide variations in individual emission point characteristics during mining operations, the size of each area source was equated to the area of disturbed acreage. For the calculation of annual average concentrations, disturbed acreage is defined as that portion of land where ongoing mining operations are active in combination with previously mined, unreclaimed acreage. Table R4-58 depicts the disturbed acreage used in the annual average simulations for each mine. For 24-hour average calculations, it is assumed that disturbed acreage on any one day would not exceed 25 acres. This is a realistic representation considering the wide variations in individual emission points during mining operations. Therefore, the size of each area source for all mines associated with disturbed acreage greater than 25 for the annual average analysis was reduced for the short-term modeling.

ERTAQ Model Description. The ERTAQ computer program is a Gaussian plume dispersion model that computes concentration resulting from a configuration of area sources. The model computes the concentrations of pollutants at a set of specified "receptor sites" for the assigned atmospheric stability, wind direction, and wind speed.

TABLE [illegible]-55

1980 TSP EMISSIONS FROM COAL MINES IN ES REGION

(Tons per Year)

	North Block	Twin Creek	South Haystack	Black Butte	Long Canyon	Winton*	Reliance*	Total
Overburden Removal	-	648	382	1,121	NA			2,151
Ore Loading	-	125	75	270	25			495
Truck Dumping	-	25	15	54	5			99
Train Loading	NA	2.5	1.5	5.4	0.5			9.9
Conveying	-	12.5	7.5	27	2.5			49.5
Coal Storage	NA	0.7	0.4	1.5	3.4			6.0
Crushing (primary)	-	1.2	0.8	2.7	0.2			4.9
Crushing (secondary)	-	4	2.4	8.6	NA			15.0
Overburden Dump Disturbance	-	255	240	NA	NA			495
Employee Access Roads	33	1.4	38	43	70.5			186.2
Haul Roads (coal)	-	105.5	15.5	357	NA			478
Haul Roads (overburden)	-	359	570	NA	NA			929
Haul Road Repair	-	56	56	56	NA			168
Dozers (overburden dumps)	56**	81	56	224	NA			417
Wind Erosion	245	729	624	1,020	135			2,753
Total	334	2,405	2,084	3,190	242			8,256

*These mines are not operational in 1980.

**Associated with initial construction activities.

NA means not applicable.

-Operation not active in 1980.

TABLE 56

1985 TSP EMISSIONS FROM COAL MINES IN ES REGION

(Tons per Year)

	North Block	Twin Creek	South Haystack	Black Butte	Long Canyon	Winton	Reliance	Total
Overburden Removal	133	648	763	1,435	NA	NA	NA	2,979
Ore Loading	70	125	150	330	100	100	25	900
Truck Dumping	14	25	30	66	20	20	5	180
Train Loading	NA	2.5	3.0	6.6	2	2	0.5	16.6
Conveying	7	12.5	15	33	10	10	2.5	90
Coal Storage	NA	0.7	0.8	1.8	13.5	0.5	0.1	17.4
Crushing (primary)	0.7	1.2	1.5	3.3	1.0	1.0	0.2	8.9
Crushing (secondary)	5.6	4	4.8	10.6	NA	NA	NA	25
Overburden Dump Disturbance	50	180	-	NA	NA	NA	NA	230
Employee Access Roads	132	1.1	32	37	125	35	8.7	371
Haul Roads (coal)	158	105	31	437	NA	NA	NA	731
Haul Roads (overburden)	40	222	-	NA	NA	NA	NA	262
Haul Road Repair	56	56	56	56	NA	NA	NA	224
Dozers (overburden dumps)	56	81	56	224	NA	NA	NA	417
Wind Erosion	299	1,702	453	2,111	135	36	36	4,772
Total	1,021	3,166	1,596	4,751	406	204	78	11,223

*Considered in the cumulative impact analysis section of this chapter.

NA means not applicable

-Operation not active in 1985.

TABLE [illegible]-57

1990 TSP EMISSIONS FROM COAL MINES IN ES REGION

(Tons per Year)

	North Block	Twin Creek	South Haystack	Black Butte	Long Canyon	Winton	Reliance	Total
Overburden Removal	133	648	763	960	NA	NA	NA	2,504
Ore Loading	70	125	150	315	100	100	25	885
Truck Dumping	14	25	30	63	20	20	5	177
Train Loading	NA	2.5	3.0	6.3	2	2	0.5	16.3
Conveying	7	12.5	15	31.5	10	10	2.5	88.5
Coal Storage	NA	0.7	0.8	1.7	13.5	0.5	0.1	17.3
Crushing (primary)	0.7	1.2	1.5	3.2	1.0	1.0	0.2	8.8
Crushing (secondary)	5.6	4	4.8	10.1	NA	NA	NA	21.2
Overburden Dump Disturbance	-	-	-	NA	NA	NA	NA	-
Employee Access Roads	132	1.1	32	37	125	34.8	8.7	370.9
Haul Roads (coal)	157.5	158	31	417	NA	NA	NA	763.5
Haul Roads (overburden)	-	-	-	NA	NA	NA	NA	-
Haul Road Repair	56	56	56	56	NA	NA	NA	224
Dozers (overburden dumps)	56	80.6	56	224	NA	NA	NA	416.6
Wind Erosion	298	1,434	550	1,861	135	36	36	4,350
Total	930	2,549	1,693	3,986	406	204	78	9,843

*Considered in the cumulative impact analysis section of this chapter.

NA Means not applicable.

- Operation not active in 1990.

TABLE R4-58

ACRES DISTURBED EQUALS SIZE OF AREA SOURCE IN ERTAQ MODELING

	1980	1985	1990
Long Canyon	542	542	542
Black Butte	1,399	3,303	2,996
North Block	216	316	311
South Haystack	743	566	671
Twin Creek	643	1,536	1,423
Winton*		140	140
Reliance*		90	90

*Considered in the cumulative impact analysis section of this chapter.

The model calculations are based on multiple applications and integrated forms of the Gaussian plume equation, which represents the concentration pattern downwind from a point source. The general form of the equation is:

$$\chi_{(0,0,z)} = \frac{q(x,y,H)}{2\pi\sigma_y\sigma_z u} \exp\left[1/2\left(\frac{y}{\sigma y}\right)^2\right] \cdot$$

$$\exp\left[-1/2\left(\frac{z-H}{\sigma_z}\right)^2\right] + \exp\left[-1/2\left(\frac{z+H}{\sigma_z}\right)^2\right] \qquad \text{(R4-31)}$$

where

(x,y,z)	are the upwind, cross-wind, and vertical components of a cartesian coordinate system, such that the receptor point is located at, or vertically above, the origin (expressed in units of length) and the source at the point $(x,-y,H)$
H	is the effective height of emission and, therefore, the centerline height of the plume (length)
q	is the source strength (mass/time)
σ_y,σ_z	are dispersion coefficients that are measures of cross-winds and vertical plume spread. These two parameters are functions of downwind distance and atmospheric stability (length)
u	is average wind speed (length/time)

Figure R4-1 illustrates the geometry for the plume equation. The source base is at $z = 0$ in the coordinate system, and the plume centerline reaches an equilibrium height H at some distance downwind from the source. The equation is based on the following important assumptions.

- The mean wind speed and direction in the vicinity of the emissions source are constant throughout the period of interest.

- When the effluent plume enters the atmosphere, it rises until it reaches an equilibrium altitude, H.

- At any downwind distance, the maximum concentration occurs at the plume centerline. The distribution of concentration values off the centerline is given by the product of two Gaussian distributions, one in the y-direction and one in the z-direction.

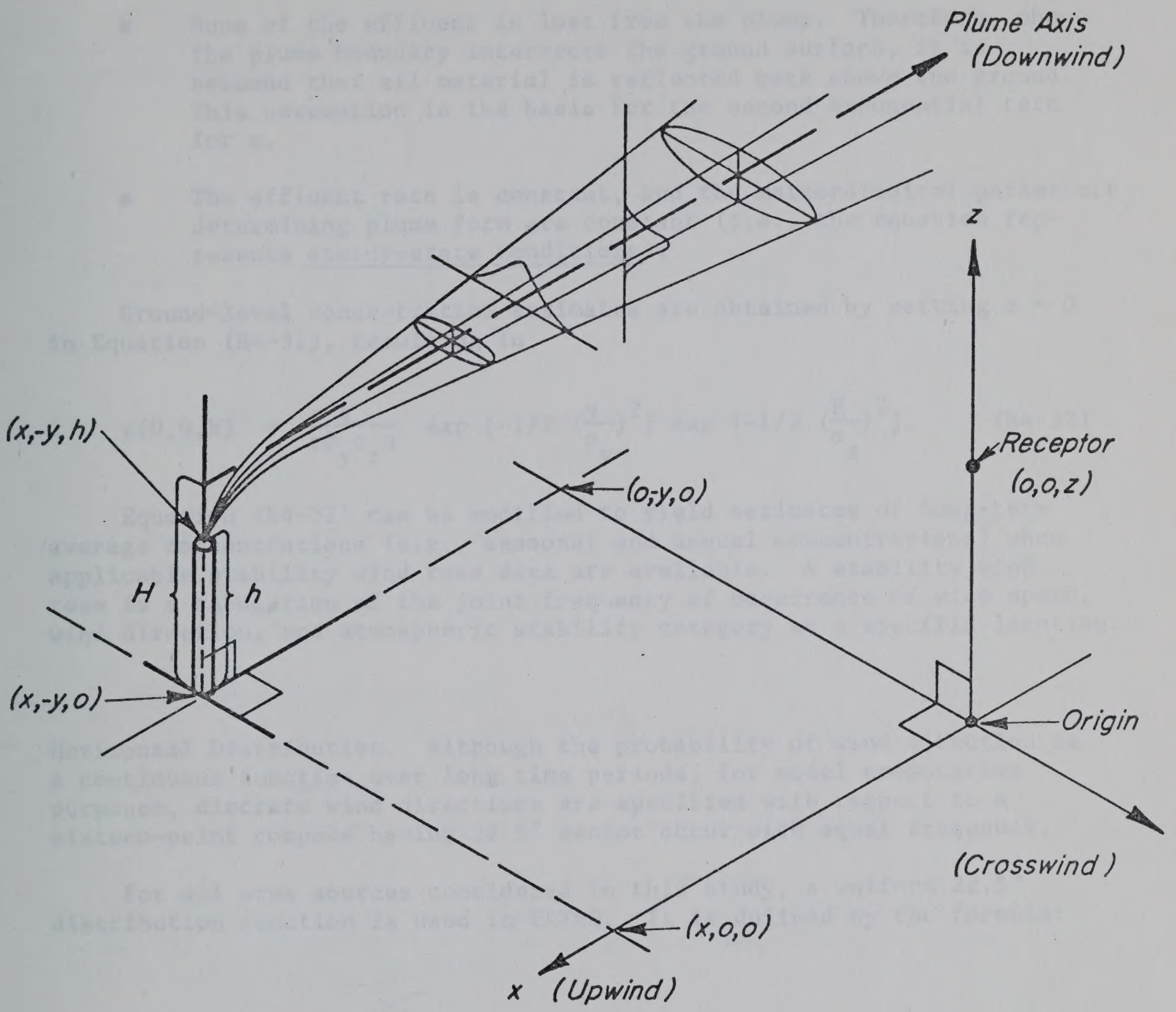
Plume Axis
(Downwind)
z
(x,-y,h)
Receptor
(o,o,z)
(o,-y,o)
H
h
(x,-y,o)
Origin
y
(Crosswind)
(x,o,o)
x (Upwind)

Figure R4-1

Coordinate System Showing Gaussian Distributions in the Crosswind and Vertical Directions

- The concentration profiles described by the Gaussian form are not "instantaneous" plume profiles. Instead they represent concentrations averaged over a short time (one hour).
- None of the effluent is lost from the plume. Therefore, when the plume boundary intersects the ground surface, it is assumed that all material is reflected back above the ground. This assumption is the basis for the second exponential term for z.
- The effluent rate is constant, and the meteorological parameters determining plume form are constant (i.e., the equation represents steady-state conditions).

Ground-level concentration estimates are obtained by setting z = 0 in Equation (R4-31), resulting in

$$\chi(0,0,H) = \frac{q}{\pi \sigma_y \sigma_z u} \exp\left[-1/2 \left(\frac{y}{\sigma_y}\right)^2\right] \exp\left[-1/2 \left(\frac{H}{\sigma_z}\right)^2\right]. \qquad \text{(R4-32)}$$

Equation (R4-32) can be modified to yield estimates of long-term average concentrations (e.g., seasonal and annual concentrations) when applicable stability wind rose data are available. A stability wind rose is a tabulation of the joint frequency of occurrence of wind speed, wind direction, and atmospheric stability category at a specific location.

Horizontal Distribution. Although the probability of wind direction is a continuous function over long time periods, for model computation purposes, discrete wind directions are specified with respect to a sixteen-point compass having 22.5° sector occur with equal frequency.

For all area sources considered in this study, a uniform 22.5° distribution function is used in ERTAQ. It is defined by the formula:

$$\text{hdf}(x, y) = \begin{cases} \frac{1}{c} & \text{if } |y| \leq \frac{c}{2} \\ 0 & \text{if } |y| > \frac{c}{2} \end{cases} \qquad \text{(R4-33)}$$

where

$$c = 2 \times \tan(11.25°) = 0.398 \times$$

Vertical Distribution. The vertical distribution function used by ERTAQ that was applied to all area sources in the ES region is the well-known Gaussian distribution, adjusted to include perfect reflection off the surface $z = 0$ and complete mixing (after a varying distance depending on stability and mixing depth) throughout the mixing layer. The precise distribution is:

$$\mathrm{vdf}(x,z,H) = \begin{cases} y(x,z,H) & \text{if } x \le x_T \\ \left(2 - \frac{x}{x_T}\right) y(x,z,H) + \left(\frac{x}{x_T} - 1\right) \frac{1}{DM} & \text{if } x_T \le x \le 2x_T \\ \frac{1}{DM} & \text{if } x > 2x_T \end{cases} \quad \text{(R4-34)}$$

where $y(x,z,H)$ is the reflected Gaussian equation

$$y(x,z,H) = \frac{1}{\sqrt{2\pi}\,\sigma_z} \exp\left(-\frac{1}{2}\left(\frac{z+H}{\sigma_z}\right)^2\right) + \exp\left(-\frac{1}{2}\left(\frac{z-H}{\sigma_z}\right)^2\right)$$

where

DM is the mixing depth (m)

σ_z is the vertical dispersion coefficient (m)

x_T is the trapping distance (m)

(x_T, the trapping distance is that distance (m) at which $\sigma_z = 0.47$ DM)

The values of the dispersion parameters σ_z used in ERTAQ to simulate the dispersion of emissions from emission sources were those of Calder (1971) expressed in the functional form:

$$\sigma_z = ax^b + c$$

The values a, b, and c are specified by downwind distance as shown in Table R4-59.

Calculation of Long-Term Averages. To calculate a long-term (annual) average for a specific source-receptor configuration, an estimate of χ is obtained by choosing a representative wind speed for each wind speed class and solving the appropriate equation for all wind speed and

TABLE R4-59

DISPERSION PARAMETERS USED IN CALCULATING VERTICAL PLUME DISPERSION (σ_z)

Stability Class	x < 100 m			100 m < x < 1000 m			x < 1000 m		
	a	b	c	a	b	c	a	b	c
1 Very Unstable	0.174	0.936	0.0	0.011	1.89	9.6	0.001	1.89	9.6
2 Moderately Unstable	0.143	0.922	0.0	0.048	1.11	2.0	0.048	1.11	2.0
3 Slightly Unstable	0.123	0.905	0.0	0.119	0.196	0.0	0.119	0.915	0.0
4 Neutral	0.080	0.881	0.0	0.187	0.775	-1.4	2.61	0.450	-25.5
5 Stable	0.060	0.845	0.0	0.135	0.745	-1.1	52.6	0.150	-126.0

stability classes appropriate for the time period in the geographical area of interest. The average concentration, χ is obtained by assuming all concentrations and weighing each one according to its frequency for the particular wind direction, wind speed class, and stability class. The average concentration is:

$$\bar{\chi} = \sum_{K} \sum_{L} \sum_{J} F(J,K,L) \; \chi(J,K,L) \qquad \text{(R4-35)}$$

where

$F(J,K,L)$ is the normalized frequency during the period of interest for wind direction interval K, wind speed class J, and stability class L

$\bar{\chi}(J,K,L)$ is the average ground-level concentration calculated from Equations (R4-33) or (R4-34) as appropriate

The total concentration at a specific receptor is obtained by summing the results of Equation (R4-35) over all sources. For each of the sixteen wind direction intervals, wind speed is defined in six categories and stability class in five categories. Thus, a three-dimensional array of 480 categories is established. Vertical variations in wind direction are not accounted for in the calculation of χ. The representative speeds adopted for the six climatological wind speed categories (0-3, 4-6, 7-10, 11-16, 17-21, and greater than 21 knots) are 2, 5.5, 10, 15.5, 21.5, and 28 mph.

The five stability categories (L = 1, 2, 3, 4, and 5, in order of increasing atmospheric stability) were derived from surface level meteorological observations as defined by Turner (1964). Stability in the lowest part of the atmosphere is determined primarily by the net heating (or cooling) of the ground surface, and by local wind speed. Turner's classification is based on surface wind speed, cloud cover, and ceiling, supplemented by solar elevation data (latitude, time of day, and time of year); thus the stability estimates can be obtained for any Weather Bureau Station at which continuous surface level observations have been made. Figure R4-2 gives a summary of these wind and stability categories.

For ground-level area sources of particulate emissions, zero plume rise is assumed. However, an initial mixing volume of 30 feet for area sources of mine operations is assumed. This feature allows the pollutant to form "puffs" of the specified depth before dispersing downwind.

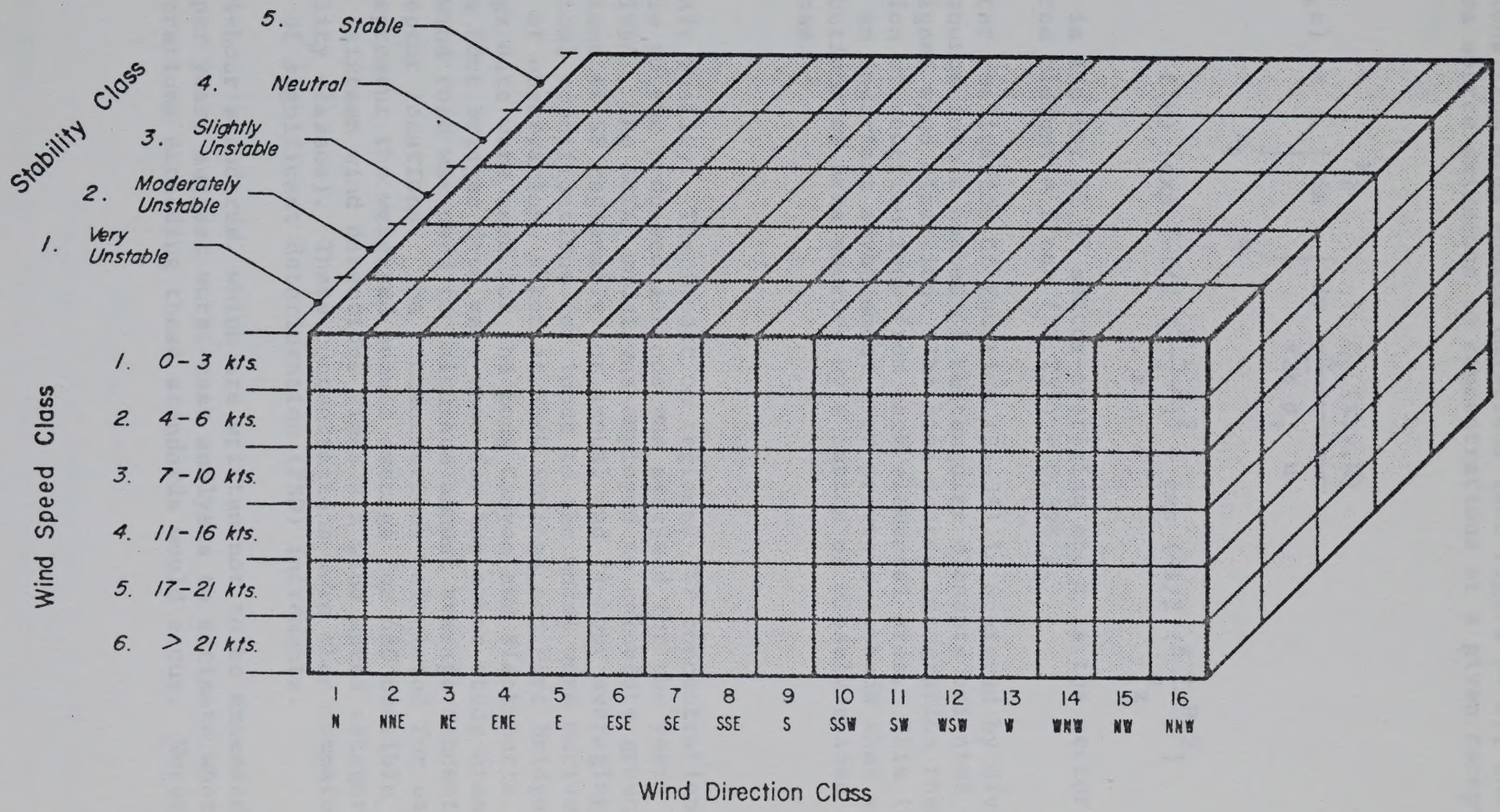
Stability Class
5. Stable
4. Neutral
3. Slightly Unstable
2. Moderately Unstable
1. Very Unstable
Wind Speed Class
1. 0-3 kts.
2. 4-6 kts.
3. 7-10 kts.
4. 11-16 kts.
5. 17-21 kts.
6. > 21 kts.
1 N
2 NNE
3 NE
4 ENE
5 E
6 ESE
7 SE
8 SSE
9 S
10 SSW
11 SW
12 WSW
13 W
14 WNW
15 NW
16 NNW
Wind Direction Class

Figure R4-2

ERTAQ Stability-Wind Rose Categories

Treatment of Area Sources. To simulate the suspended particulate (SP) concentrations from area source emissions (see Figure R4-3), the equation relates area source emissions to concentrations at a given receptor as follows:

$$\chi(o,o,z) = \int_{x_1}^{x_2} dx \int_{x} dy \frac{Q_A(x,y,H)}{\sqrt{2\pi}\,\sigma_z\,u}$$

$$f(y)\left[\exp\left(-1/2\left(\frac{z-H}{\sigma_z}\right)^2 + \exp\left(-1/2\left(\frac{z+H}{\sigma_z}\right)^2\right]\right.\right. \qquad \text{(R4-36)}$$

where f(y) is 1/c for 22.5° sector-averaging and c is the sector width at the source element = 2 tan (11.25°) = 0.398 x.

Computer realization of Equation (R4-36) is achieved by dividing each area source into a number of rectangular elements oriented perpendicular to the assigned wind direction. The area source integration then involves the summation of contributions from each elemental area. This technique represents an important advancement over previous methods that simulate the contributions of area sources by a series of closely-spaced virtual point sources.

Impact on Air Quality. The impact on regional TSP concentrations attributable to the proposed actions was assessed for the years 1980, 1985, and 1990. The ERTAQ model was employed to calculate ground-level concentrations of SP regionally for annual and 24-hour averaging periods. Meteorological specifications for input to the model were derived from five years of observations taken at Rock Springs and Fort Bridger. The Rock Springs data were used for the Long Canyon and Black Butte study areas. The Fort Bridger data were used for the other study areas. A stability wind rose was used to calculate annual average concentrations at 128 receptor locations. The concentrations calculated for each receptor represent the weighted annual average for 480 possible weather conditions (sixteen wind directions times six wind speed categorie times five stability classes). These concentrations were then compared to the prevention of significant deterioration (PSD) increments.

The 24-hour standards, which are written not to be exceeded more than once per year, suggest worst-case analyses to estimate whether or not concentrations exceeding these standards would occur. Worst-case

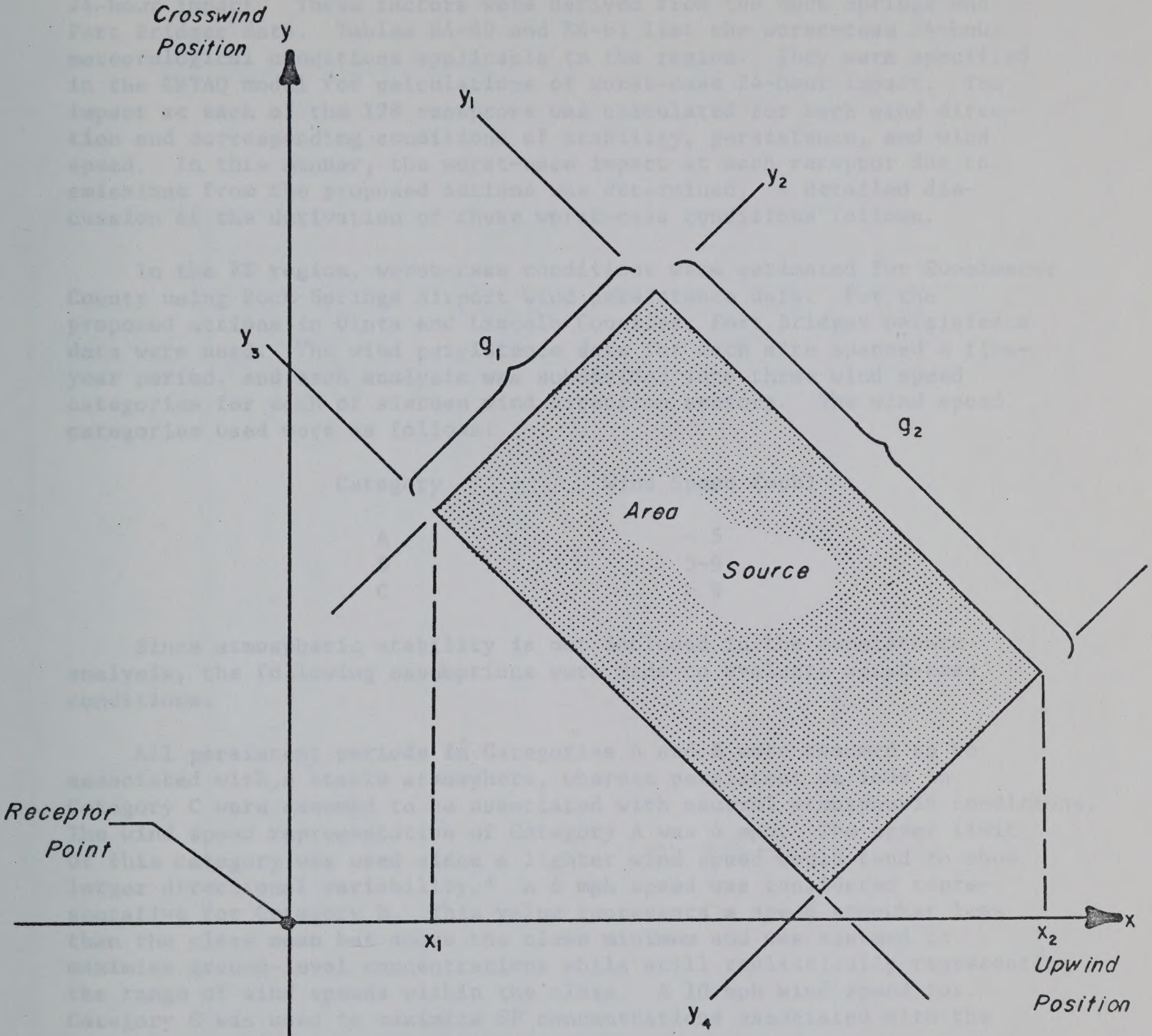
Crosswind Position
y
y1
y2
y3
g1
g2
Area
Source
Receptor Point
x1
x2
x
Upwind Position
y4

Figure R4-3

Geometry for Area Source with Dimensions g_1 g_2 in the Horizontal Plane, Shown in the Receptor-Centered Wind Oriented Coordinate System

24-hour conditions are defined as the combination of poor atmospheric dispersion conditions and wind direction persistence leading to maximum 24-hour impact. These factors were derived from the Rock Springs and Fort Bridger data. Tables R4-60 and R4-61 list the worst-case 24-hour meteorological conditions applicable to the region. They were specified in the ERTAQ model for calculations of worst-case 24-hour impact. The impact at each of the 128 receptors was calculated for each wind direction and corresponding conditions of stability, persistence, and wind speed. In this manner, the worst-case impact at each receptor due to emissions from the proposed actions was determined. A detailed discussion of the derivation of these worst-case conditions follows.

In the ES region, worst-case conditions were estimated for Sweetwater County using Rock Springs Airport wind persistence data. For the proposed actions in Uinta and Lincoln Counties, Fort Bridger persistence data were used. The wind persistence data for each site spanned a five-year period, and each analysis was subdivided into three wind speed categories for each of sixteen wind direction sectors. The wind speed categories used were as follows:

Category	Wind Speed (mph)
A	< 5
B	5-9
C	> 9

Since atmospheric stability is not included in the persistence analysis, the following assumptions were made to evaluate worst-case conditions.

All persistent periods in Categories A and B were assumed to be associated with a stable atmosphere, whereas persistent periods in Category C were assumed to be associated with neutral atmospheric conditions. The wind speed representative of Category A was 4 mph. The upper limit of this category was used since a lighter wind speed would tend to show larger directional variability.* A 6 mph speed was considered representative for Category B. This value represents a speed somewhat less than the class mean but above the class minimum and was assumed to maximize ground-level concentrations while still realistically representing the range of wind speeds within the class. A 10 mph wind speed for Category C was used to maximize SP concentrations associated with the assumed neutral dispersion conditions.

The ratios of resulting 1-hour average concentrations between each of the three classes were evaluated as follows:

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*The general trend of increased persistence with faster wind speeds was discussed in Chapter 2.

TABLE R4-60

WORST-CASE 24-HOUR METEOROLOGICAL CONDITIONS FOR IMPACT OF GROUND-LEVEL SOURCES AT ROCK SPRINGS

Wind Direction	Atmospheric Stability			
	Stable		Neutral	
	Persistence (hours)	Wind Speed (mph)	Persistence (hours)	Wind Speed (mph)
N	4	4	-	-
NNE	4	4	-	-
NE	-	-	24	10
ENE	-	-	16	10
E	7	4	-	-
ESE	6	4	-	-
SE	9	6	-	-
SSE	6	6	-	-
S	13	4	-	-
SSW	5	4	-	-
SW	-	-	24	10
WSW	12	4	8	4
W	8	4	-	-
WNW	-	-	15	10
NW	8	6	-	-
NNW	3	4	-	-

TABLE R4-61

WORST-CASE 24-HOUR METEOROLOGICAL CONDITIONS FOR IMPACT OF GROUND-LEVEL SOURCES AT FORT BRIDGER

Wind Direction	Atmospheric Stability			
	Stable		Neutral	
	Persistence (hours)	Wind Speed (mph)	Persistence (hours)	Wind Speed (mph)
N	6	4	–	–
NNE	4	6	–	–
NE	6	6	–	–
ENE	12	4	1	4
E	11	6	–	–
ESE	12	6	1	6
SE	7	4	–	–
SSE	3	4	–	–
S	6	6	–	–
SSW	–	–	9	10
SW	–	–	15	10
WSW	12	6	2	6
W	14	6	1	6
WNW	12	4	1	4
NW	12	4	4	4
NNW	4	6	–	–

$$R1 = \frac{\chi_C}{\chi_A} = 0.40$$

$$R2 = \frac{\chi_C}{\chi_B} = 0.60$$

$$R3 = \frac{\chi_B}{\chi_A} = 0.67$$

where the notation,

χ_A represents 1-hour average SP concentration under stable conditions and a wind speed of 4 mph.

χ_B represents 1-hour average SP concentration under stable conditions and a wind speed of 6 mph.

χ_C represents 1-hour average SP concentration under neutral conditions and a wind speed of 10 mph.

Clearly, both the wind speed and stability (therefore distance) are the weighting factors in the first two ratios, whereas wind speed is the only weighting factor for the third ratio. However, the first two ratios were assumed constant, since their variation with distance resulting from stability differences is within a few percent. Consequently, 24-hour concentrations were calculated as follows:

$$\chi_{24A} = \chi_A \times \frac{PST_A}{24}$$

where PST_A represents the number of hours of persistence for wind speed Class A and a given wind direction sector.

A subsequent comparison of the persistence maxima between the three wind speed classes for each wind direction could be made to determine a worst-case condition.

However, stable atmospheric conditions were assumed to be generally associated with the development of nocturnal inversions. A 14-hour limit of stable conditions was assumed if longest persistent periods occurred in the winter, a 12-hour limit in the spring and fall, and a 10-hour limit in the summer. Therefore, if a given wind direction had a persistent period greater than the seasonal limit adopted, the difference in hours between the persistent period and the seasonal limit was assumed to have neutral conditions and the same wind speed.

Uncertainties Associated with Modeling Fugitive Dust Emissions

Prior to evaluating the numerical results of this analysis, it is essential to denote the uncertainties associated with the modeling of fugitive dust from coal mines. Although the ERTAQ model and its application herein is considered state-of-the-art technology, inherent assumptions need to be stressed.

Meteorological Data. As previously discussed, because of the lack of on-site data, meteorological specifications for model input were derived from five years of observations taken at Rock Springs and Fort Bridger. The distance between these meteorological stations and the corresponding mines ranges from 12 to 36 miles. It is unlikely that the same conditions (wind speed, wind direction, and stability) recorded at the meteorological stations would have been concurrently observed at the mine sites. The differences in meteorology experienced by the two locations can occur on three scales: (1) microscale effects of topography on local wind speed and mechanical turbulence and the effect of local vegetative cover on surface heating and, hence, the thermal turbulence (i.e., stability); (2) the mesocale differences, such as local cloud cover, thunderstorm activity, squall lines etc., that can cause differences in stability, wind speed, and wind direction; and (3) synoptic scale effects of cyclonic weather systems on wind direction. Therefore, the degree to which the Rock Springs and Fort Bridger data are representative of the meteorology at the mine locations is unknown.

Emission Rates. In addition to the limitations pertaining to the reliability of emission factor derivation, the model simulations assume the effluent rate to be constant to represent steady-state conditions. That is, the emission rates depicted in Tables R4-55, 56, and 57 are assumed to characterize fugitive dust emissions from the mine for annual as well as 24-hour average model calculations. Such an assumption indicates that the mining operations considered are continuous, without variation. The actual worst-case impact of emissions from the mine during any hour is a function of the joint occurrence of specific dust-producing activities and local worst-case meteorology. Since activity at any one mine is bound to fluctuate daily or even hourly, a degree of uncertainty is inherent in the model simulations.

Source-Receptor Geometry. In this study, the mines were modeled as area sources; the size of each area source was equated to the disturbed acreage calculated for each analysis year. Therefore, emission rates incorporating all types of mining activities were uniformly distributed across a single area source. This neglects the actual variation in specific source locations and dimensions (such as haul roads, shoveling, and dragline activities) that are actually a combination of line, point, and smaller area sources, not withstanding the actual exposed acreage vulnerable to wind erosion. The effect of a more realistic source geometry characterization would be most noticeable at sensitive receptors

located near the mine sites where the highest concentrations are predicted to occur. Hence, another degree of uncertainty is introduced into the model calculations due to the lack of detailed source-receptor geometries.

Topography. Because of time constraints, lack of data, and model limitations, the effect of topography on local diffusion characteristics was not considered in this analysis. That is, the whole ES region, approximately 180 miles by 150 miles, was assumed to be flat. As discussed in Chapter 2, the ES region is actually contained within a broad mountain basin interspersed with much irregular terrain. The extent to which such terrain would affect the dispersion of fugitive dust emissions from the coal mines is unknown.

Deposition. Deposition, although somewhat inherent in the derivation of emission factors, is not included in the ERTAQ model due to lack of source specific information on particle characteristics. If deposition were included in the modeling of fugitive emissions, concentrations predicted during light wind speed conditions could be reduced substantially. The effect of deposition at higher wind speeds is much less because the wind energy is able to carry large particles further. However, at the present time, theoretical equations characterizing deposition of fugitive dust from coal mines have not been adequately validated. Therefore, the degree of accuracy associated with simulated SP concentrations on the scale of this regional application is questionable.

Initial Mixing Volume. For nonbuoyant fugitive dusts from ground-level area sources, zero plume rise is assumed. Emissions actually occur at various elevations and are subject to the effect of the variation in actual mine site topography and surface heating characteristics on thermally and mechanically induced turbulence. To simulate this effect, an initial mixing volume of 30 feet for area sources of mine operations is assumed. This feature allows the pollutant to form "puffs" of the specified depth before dispersing downwind. Without monitoring data for use in verification, the accuracy of such an assumption is unknown.

The purpose of this section exhibiting the uncertainties associated with the modeling of fugitive dusts is to prepare the reader for proper evaluation of the impact results presented in the following sections. When evaluating isopleths depicting annual and 24-hour average impact resulting from the most probable level of mining development, the reader must realize that the absolute value of the numbers associated with the impacts were derived from analysis techniques involving a large number of uncertainties. The important points to note are the relative contributions from the individual mines to simulated SP concentrations, as well as the relative distribution of predicted SP levels indicative of the interaction of the individual mines with one another under specific meteorological conditions. In this sense, if all the aforementioned

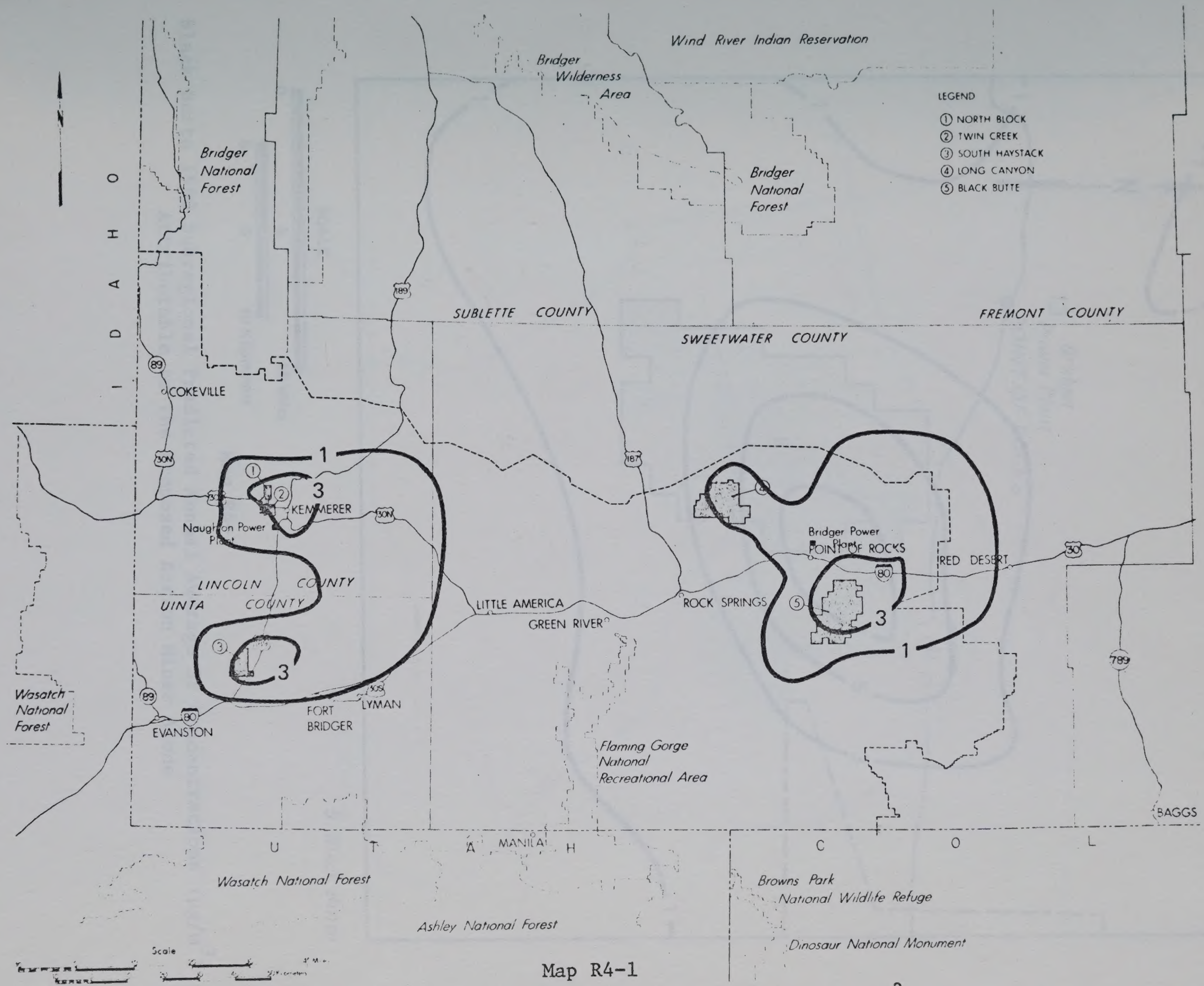
uncertainties have the same effect on each mine, the absolute values associated with the isopleths presented in the next section would change, but the predicted distribution and the contribution from each mine to simulated SP levels would not. In this manner, as the state-of-the-art technology for evaluating fugitive dust emissions improves, the value of this analysis as a guideline to evaluate relative impact from the most probable level of mining development will not change.

Model Predictions of Annual Average Impact on SP Concentrations for 1980

Map R4-1 depicts the incremental increase from the proposed actions to annual average SP concentrations in 1980. Maps R4-2 through R4-5 illustate the concentration distribution for the four subregions of highest predicted SP levels. Note that the concentrations presented in these maps are attributable to the five proposed mines alone.

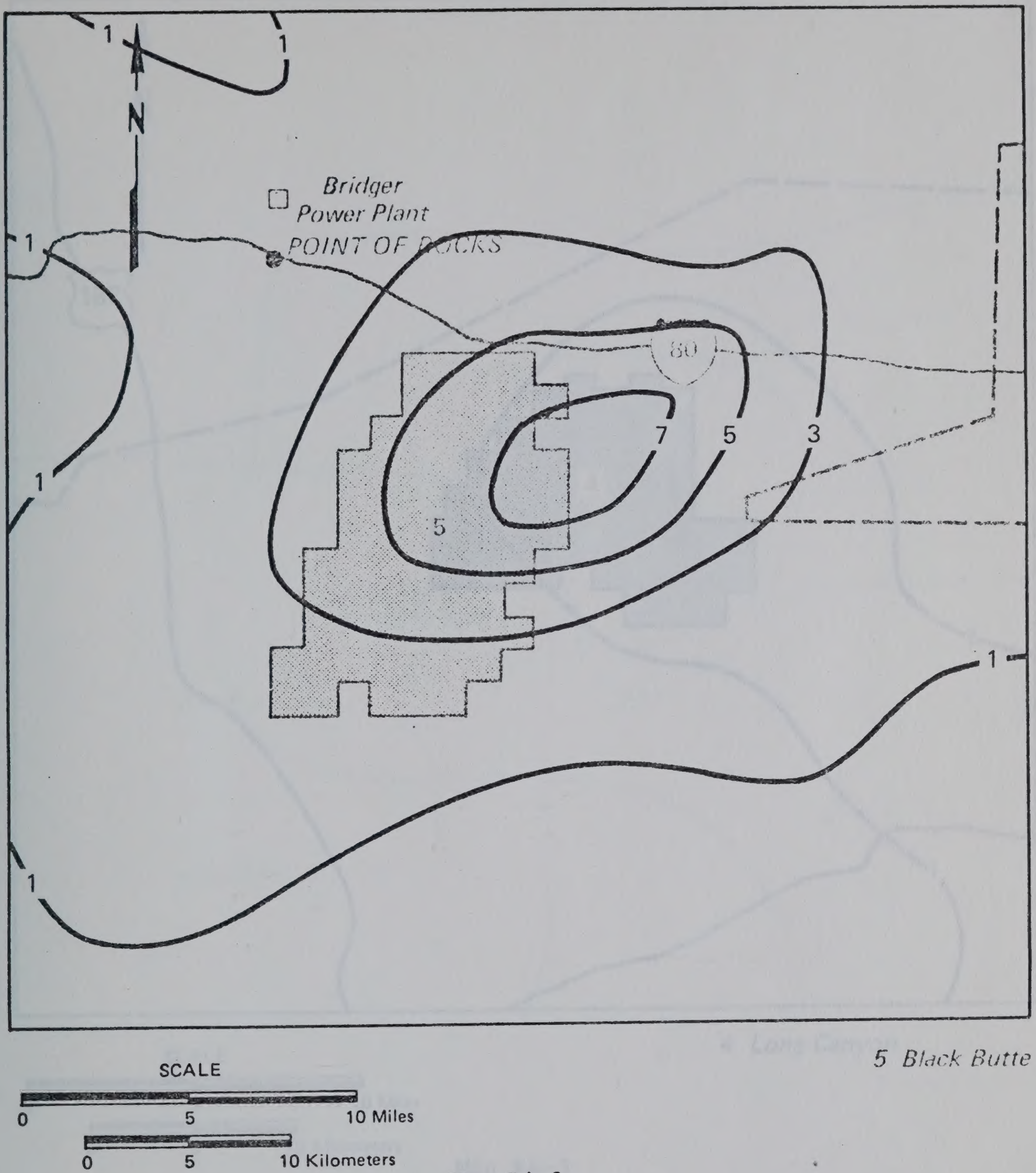
Regionally predicted annual average TSP concentrations from the mining activities range from 1 to 7 $\mu g/m^3$. The highest concentrations are predicted to occur close to the actual mine sites, and the isopleths depicting such levels are skewed to the east and northeast. This type of distribution is attributable to the predominant frequency of west and southwest winds as recorded at the Fort Bridger and Rock Springs meteorological stations. Interaction between mines lining up is not a major consideration for annual averages, since none of the proposed mines line up during predominant wind directions. The highest concentrations of approximately 7 $\mu g/m^3$ were predicted to occur in the proximity of the Black Butte mine as shown in Map R4-2. Concentrations associated with the Black Butte mine alone account for more than 96% of the 7 $\mu g/m^3$ totals. Second highest annual average SP concentrations range from 5 to 7 $\mu g/m^3$ about the Black Butte mine. The Black Butte mine alone contributes more than 92% to these predicted levels. Further downwind of Black Butte where predicted SP levels range from 1 to 3 $\mu g/m^3$, the contribution from the Black Butte mine ranges from 68 to 90%. At further downwind distances, the interaction from the other mines becomes evident. Long Canyon and North Block have a minimal effect (less than 2%) due mostly to low emission rates. Through long range transport, the South Haystack and Twin Creek mine contributions are apparent. It is evident that in the vicinity of any one mine, that particular mine will account for a major portion of predicted SP concentrations. However, predicted SP levels further downwind from a specific source consist of contributions associated with the interaction of two or more sources.

Map R4-4 depicts peak annual average SP concentrations of approximately 3 $\mu g/m^3$ in the North Block-Twin Creek subregion. North Block and Twin Creek contribute greater than 22 and 74%, respectively, to the 3 $\mu g/m^3$ SP levels adjacent to North Block; South Haystack accounts for


Wind River Indian Reservation
Bridger Wilderness Area
LEGEND
① NORTH BLOCK
② TWIN CREEK
③ SOUTH HAYSTACK
④ LONG CANYON
⑤ BLACK BUTTE
Bridger National Forest
Bridger National Forest
I D A H O
SUBLETTE COUNTY
FREMONT COUNTY
SWEETWATER COUNTY
COKEVILLE
KEMMERER
Naughton Power Plant
LINCOLN COUNTY
UINTA COUNTY
LITTLE AMERICA
GREEN RIVER
ROCK SPRINGS
Bridger Power Plant
POINT OF ROCKS
RED DESERT
FORT BRIDGER
LYMAN
EVANSTON
Wasatch National Forest
Flaming Gorge National Recreational Area
BAGGS
U T A H
MANILA
C O L
Wasatch National Forest
Ashley National Forest
Browns Park National Wildlife Refuge
Dinosaur National Monument
Scale
1
3
3
1
3
89
30N
30S
189
187
80
30
789

Map R4-1

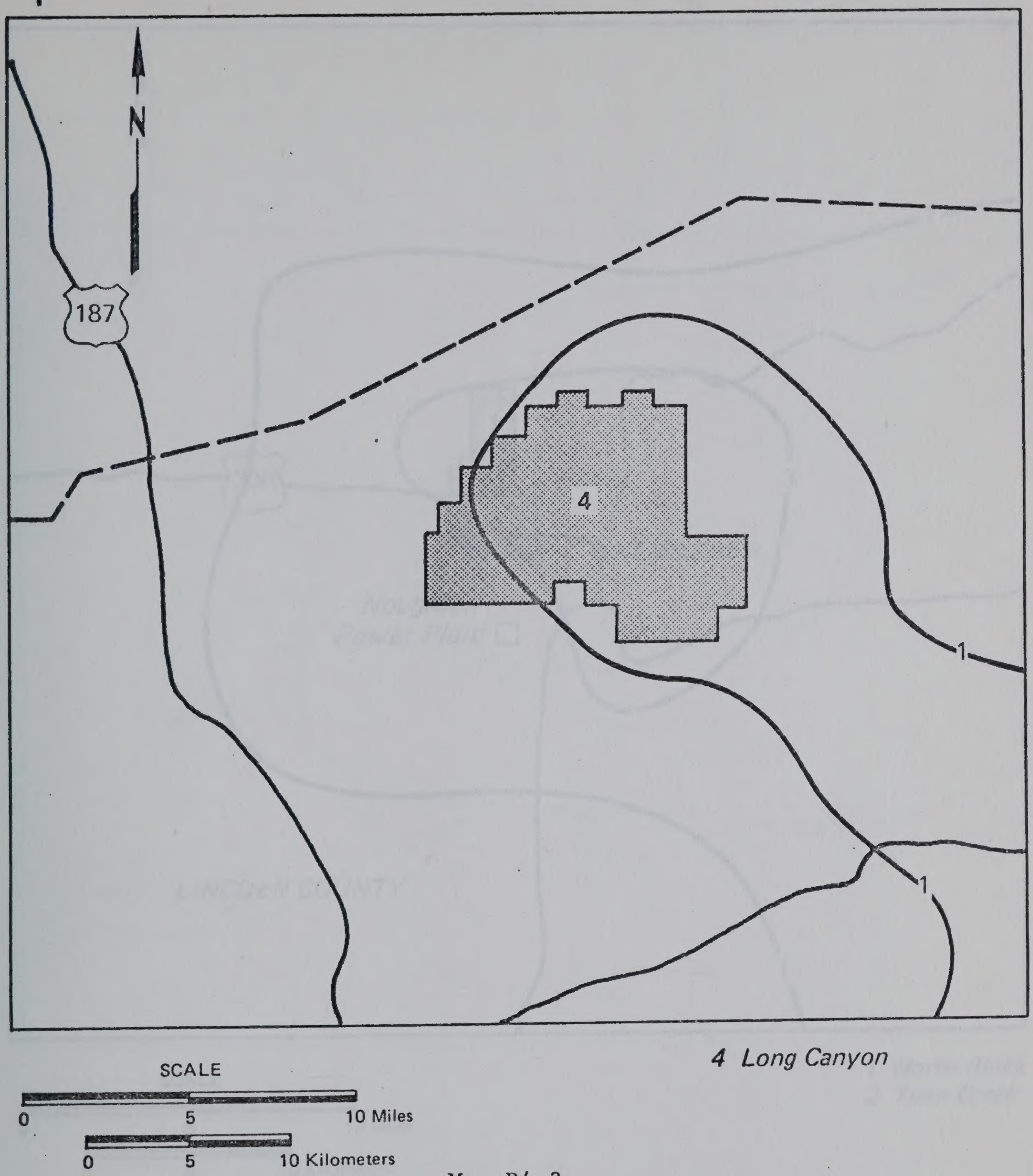
1980 Predicted Annual Average SP Concentrations ($\mu g/m^3$)
Attributable to the Proposed Action Mines Alone


1
1
N
Bridger Power Plant
POINT OF ROCKS
1
80
7
5
3
1
5
1
1
SCALE
0 5 10 Miles
0 5 10 Kilometers
5 Black Butte

Map R4-2

Black Butte 1980 Subregional Predicted Annual Average SP Concentrations ($\mu g/m^3$) Attributable to the Proposed Action Mines Alone

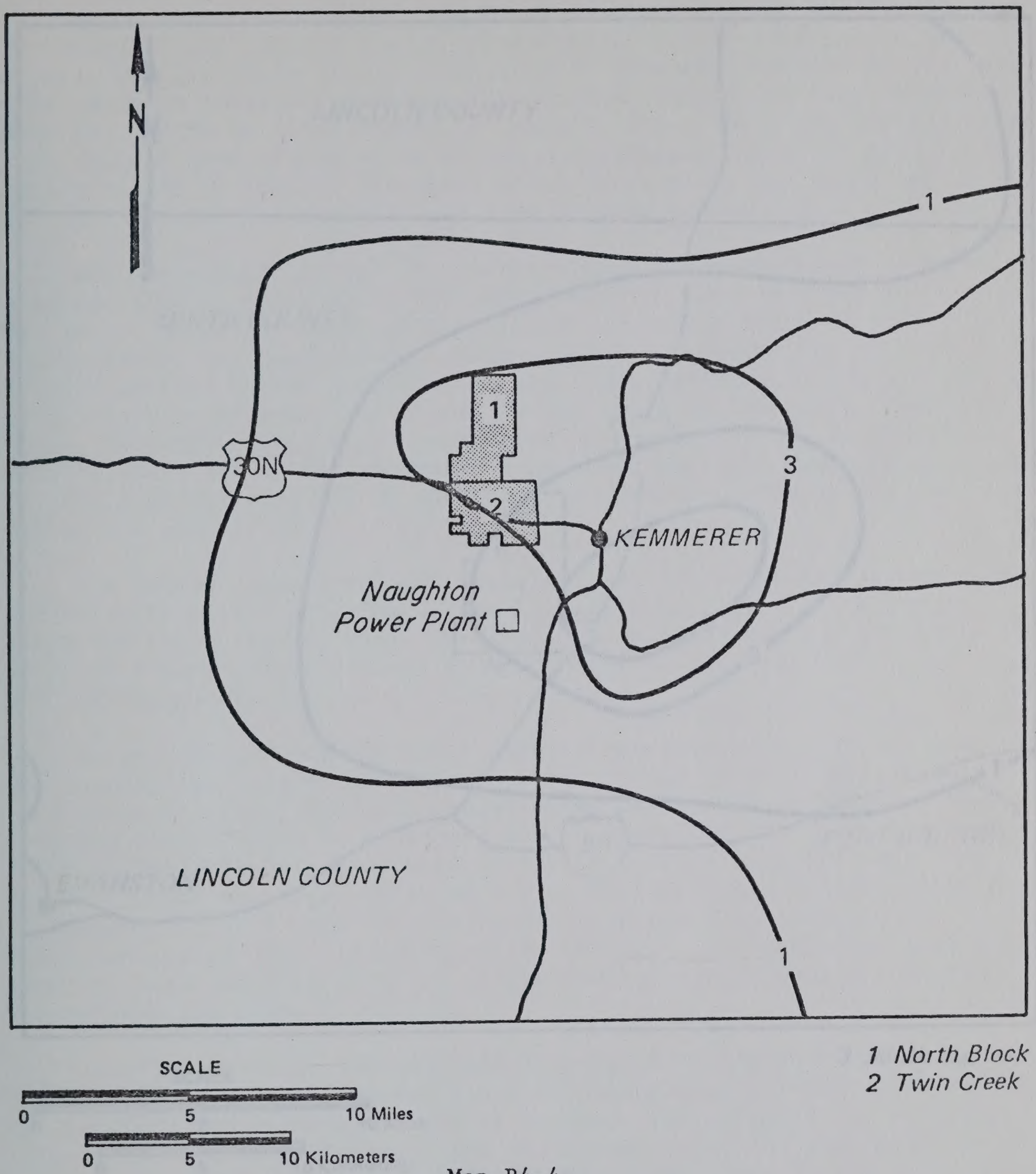
801143
803236


N
187
4
1
1
4 Long Canyon
SCALE
0
5
10 Miles
0
5
10 Kilometers

Map R4-3

Long Canyon 1980 Subregional Predicted Annual Average SP Concentrations ($\mu g/m^3$) Attributable to the Proposed Action Mines Alone

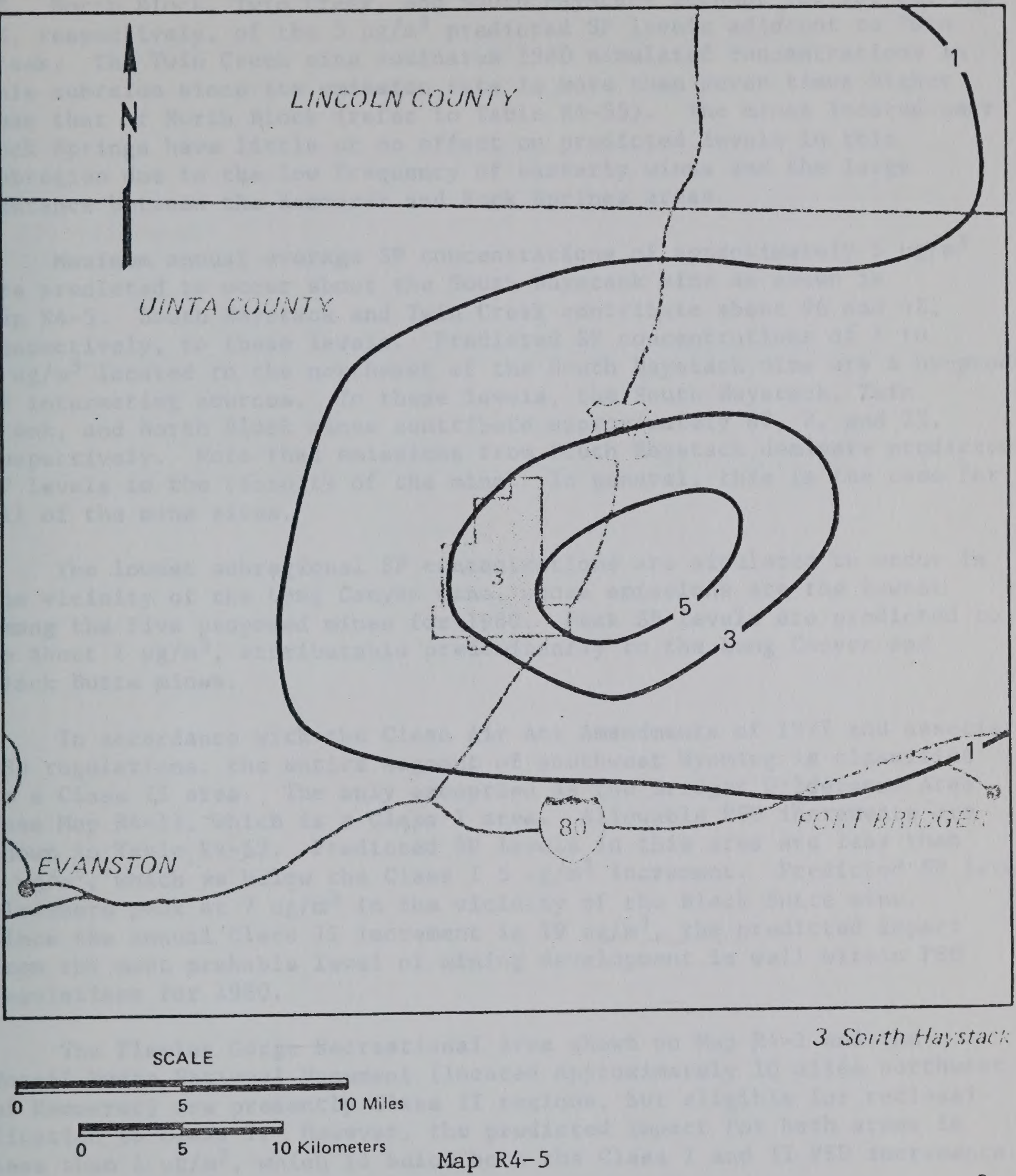
801141
803332


N
30N
1
2
KEMMERER
Naughton Power Plant
3
1
1
LINCOLN COUNTY
SCALE
0
5
10 Miles
0
5
10 Kilometers
1 North Block
2 Twin Creek

Map R4-4

orth Block - Twin Creek 1980 Subregional Predicted Annual Average SP Concentrations ($\mu g/m^3$) Attributable to the Proposed Action Mines Alone

801147
803254


N
LINCOLN COUNTY
UINTA COUNTY
1
3
5
3
1
80
FORT BRIDGER
EVANSTON
3 South Haystack
SCALE
0
5
10 Miles
0
5
10 Kilometers

Map R4-5

South Haystack 1980 Subregional Annual Average SP Concentrations (µg/m^3) Attributable to the Proposed Mines Alone

2%. North Block, Twin Creek, and South Haystack account for 10, 88, and 2%, respectively, of the 3 $\mu g/m^3$ predicted SP levels adjacent to Twin Creek. The Twin Creek mine dominates 1980 simulated concentrations in this subreion since its emission rate is more than seven times higher than that of North Block (refer to Table R4-55). The mines located near Rock Springs have little or no effect on predicted levels in this subregion due to the low frequency of easterly winds and the large distance between the Kemmerer and Rock Springs areas.

Maximum annual average SP concentrations of approximately 5 $\mu g/m^3$ are predicted to occur about the South Haystack mine as shown in Map R4-5. South Haystack and Twin Creek contribute about 96 and 4%, respectively, to these levels. Predicted SP concentrations of 1 to 3 $\mu g/m^3$ located to the northeast of the South Haystack mine are a by-product of interacting sources. To these levels, the South Haystack, Twin Creek, and North Block mines contribute approximately 87, 8, and 2%, respectively. Note that emissions from South Haystack dominate predicted SP levels in the vicinity of the mine. In general, this is the case for all of the mine sites.

The lowest subregional SP concentrations are simulated to occur in the vicinity of the Long Canyon mine, whose emissions are the lowest among the five proposed mines for 1980. Peak SP levels are predicted to be about 1 $\mu g/m^3$, attributable predominantly to the Long Canyon and Black Butte mines.

In accordance with the Clean Air Act Amendments of 1977 and associated PSD regulations, the entire segment of southwest Wyoming is classified as a Class II area. The only exception is the Bridger Wilderness Area (see Map R4-1), which is a Class I area. Allowable PSD increments are shown in Table R4-62. Predicted SP levels in this area are less than 1 $\mu g/m^3$, which is below the Class I 5 $\mu g/m^3$ increment. Predicted SP levels elsewhere peak at 7 $\mu g/m^3$ in the vicinity of the Black Butte mine. Since the annual Class II increment is 19 $\mu g/m^3$, the predicted impact from the most probable level of mining development is well within PSD regulations for 1980.

The Flaming Gorge Recreational Area shown on Map R4-1 and the Fossil Butte National Monument (located approximately 10 miles northwest of Kemmerer) are presently Class II regions, but eligible for reclassification to Class I. However, the predicted impact for both areas is less than 1 $\mu g/m^3$, which is below both the Class I and II PSD increments.

The State of Wyoming and the EPA have designated the trona patch 6 miles north of Green River as a nonattainment (NA) area. This indicates that ambient TSP levels measured in the trona patch exceeded the NAAQS at the time of NA designation. As shown in Map R4-1, annual average SP concentrations less than 1 $\mu g/m^3$ are predicted to occur in this NA area in 1980. The predicted proposed actions impact is approximately 1% of the 75 $\mu g/m^3$ federal standard.

TABLE R4-62

ALLOWABLE AIR QUALITY INCREMENTS UNDER SIGNIFICANT DETERIORATION RESTRICTIONS ($\mu g/m^3$)

	Class I	Class II	Class III
EPA Pollutant Standard TSP			
Annual	5	19	37
24-hour	10	37	75

Model Predictions of Annual Average Impact on SP Concentrations for 1985 and 1990

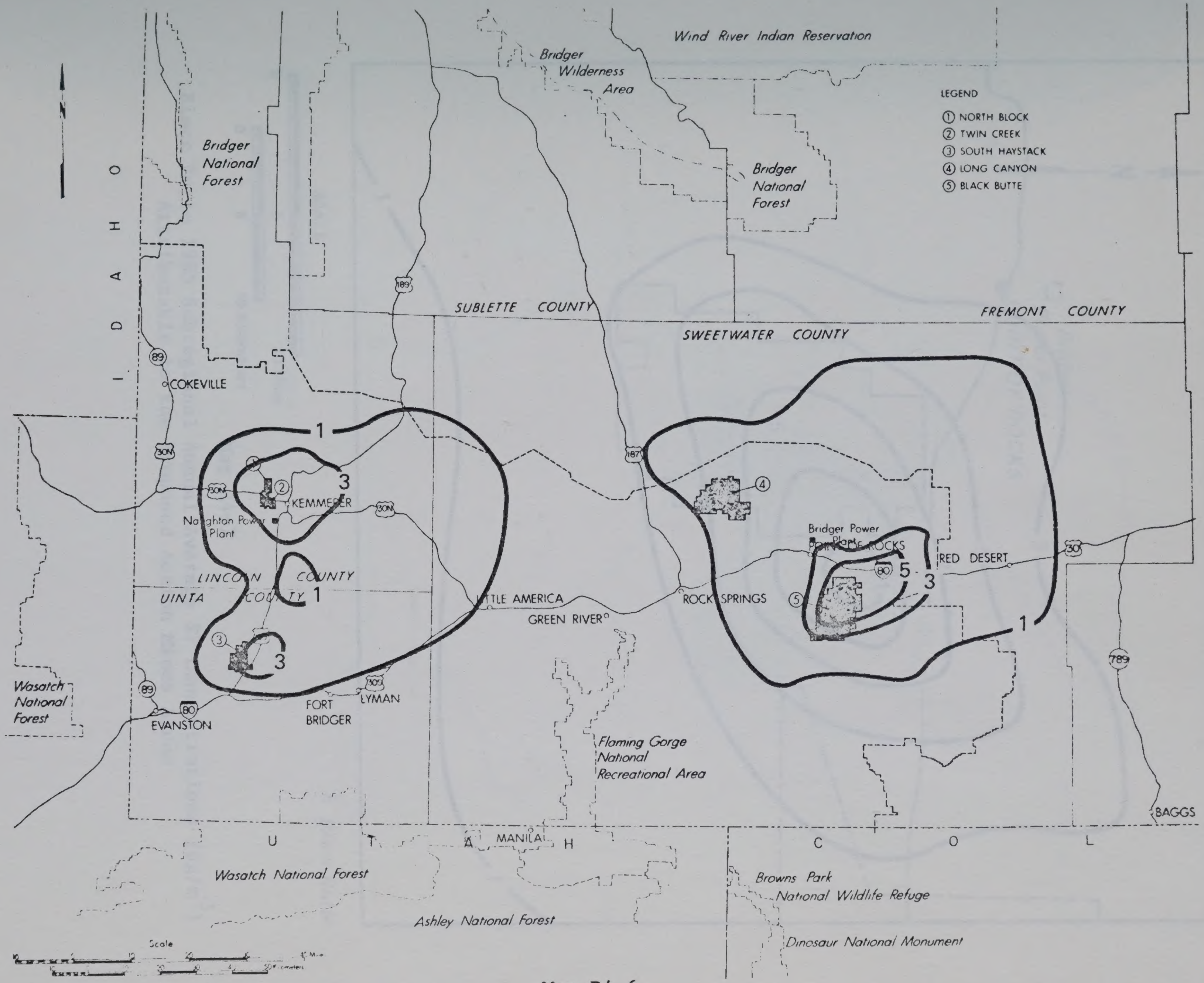
Maps R4-6 through R4-15 present the regional and subregional distributions of annual average SP concentrations for 1985 and 1990 from the five proposed mining actions alone. Except for Black Butte and Twin Creek, particulate emission rates for each proposed mine vary insignificantly from 1985 to 1990; therefore, Maps R4-6 and R4-11, depicting SP impacts for both analysis years, are very similar. Consequently, a discussion of the model predictions for annual average SP concentrations applies to both years.

Regionally, predicted SP levels attributable to the mining operations vary from 1 to 11 $\mu g/m^3$ in 1985 and 1 to 9 $\mu g/m^3$ in 1990. Since combined emission rates emanating from the proposed actions are higher in 1985 than 1990, predicted impacts are higher. As shown in the results for 1980, the highest concentrations occur close to the actual mine sites, and the isopleths depicting such levels are skewed to the east and northeast due to the predominant frequency of west and southwesterly winds. The highest concentrations of approximately 11 $\mu g/m^3$ in 1985 and 9 $\mu g/m^3$ in 1990 are predicted to occur in the vicinity of the Black Butte mine as shown by Maps R4-7 and R4-12. Concentrations resulting from emissions at the Black Butte mine alone comprise more than 96% of these maximum SP levels. Contributions from Black Butte to predicted levels of 3 to 11 $\mu g/m^3$ in 1985 and 3 to 9 $\mu g/m^3$ in 1990 range from 85 to 97% for both analysis years. Black Butte's highest contributions occur in the near vicinity of the mine and decrease with distance away from the mine.

The second highest subregional concentrations of 7 $\mu g/m^3$ are predicted to occur about the North Block and Twin Creek mines. Maps R4-9 and R4-14 depict maximum predicted SP concentrations of 7 $\mu g/m^3$ for both 1985 and 1990. The Twin Creek coal mine accounts for 82% of the simulated 5 to 7 $\mu g/m^3$ SP levels, and North Block accounts for 16%. In the area adjacent to the Twin Creek mine the remaining 2% is attributable to South Haystack. Twin Creek, North Block, and South Haystack comprise approximately 54, 44, and 2%, respectively, of the 5 to 7 $\mu g/m^3$ simulated SP concentrations adjacent to North Block, depicted in Maps R4-9 and R4-14. The Twin Creek mine dominates predicted TSP levels in this subregion, since its emission rates for 1985 and 1990 are about three times higher than those of North Block. However, contributions from the North Block mine to simulated SP concentrations can increase significantly when compared to 1980.

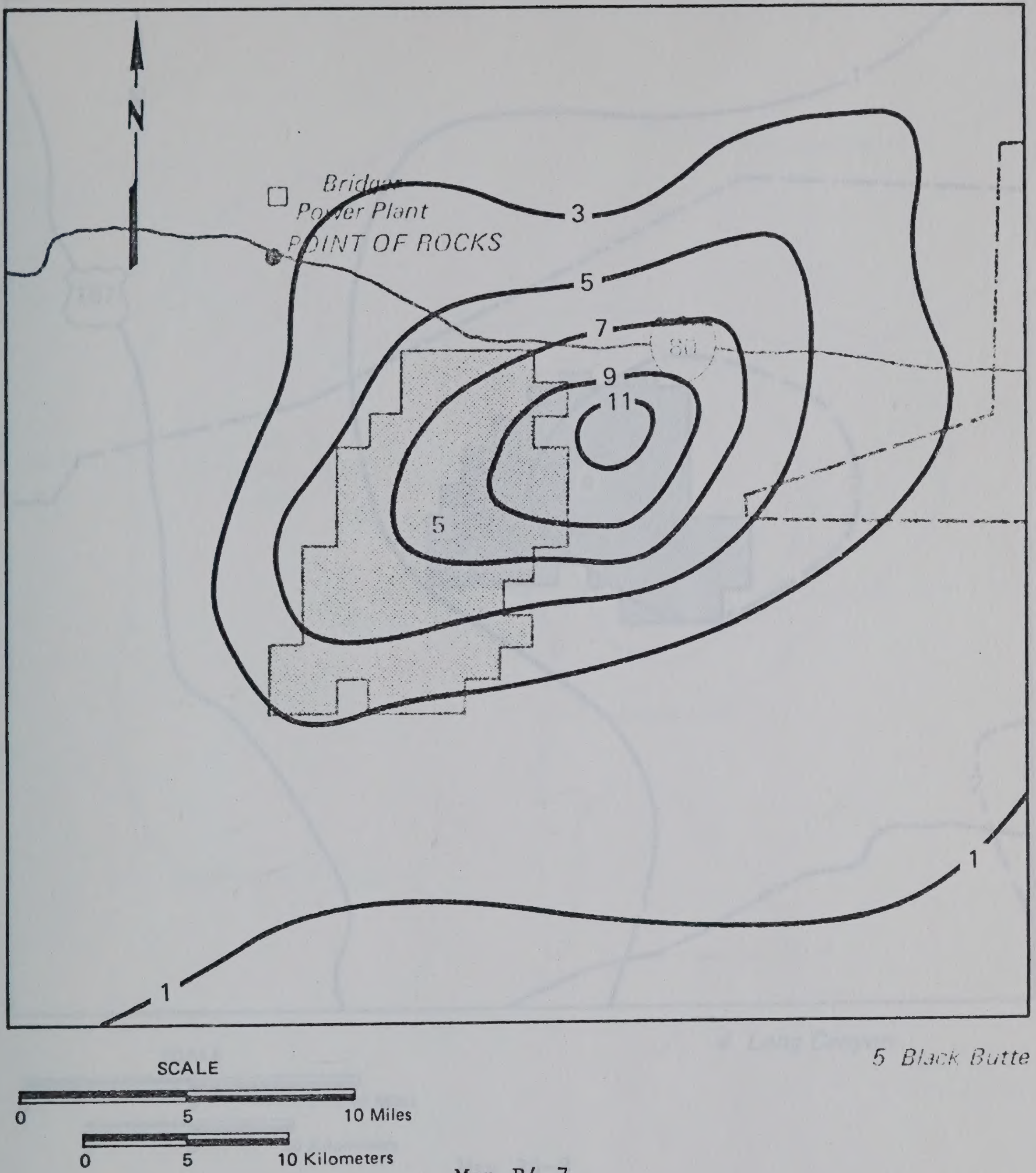
Maximum SP concentrations ranging from 3 to 5 $\mu g/m^3$ are predicted for 1985 and 1990 in the proximity of the South Haystack mine. Emissions from South Haystack account for more than 90% of these levels. The Twin Creek and North Block mines account for the remaining 10%.

803281
803283


Wind River Indian Reservation
Bridger Wilderness Area
Bridger National Forest
Bridger National Forest
LEGEND
① NORTH BLOCK
② TWIN CREEK
③ SOUTH HAYSTACK
④ LONG CANYON
⑤ BLACK BUTTE
IDAHO
SUBLETTE COUNTY
FREMONT COUNTY
SWEETWATER COUNTY
COKEVILLE
KEMMERER
Naughton Power Plant
LINCOLN COUNTY
UINTA COUNTY
LITTLE AMERICA
GREEN RIVER
ROCK SPRINGS
Bridger Power Plant
POINT OF ROCKS
RED DESERT
Wasatch National Forest
EVANSTON
FORT BRIDGER
LYMAN
Flaming Gorge National Recreational Area
BAGGS
UTAH
MANILA
COLO
Wasatch National Forest
Ashley National Forest
Browns Park National Wildlife Refuge
Dinosaur National Monument
Scale
1
3
5
89
30N
189
187
80
30
789

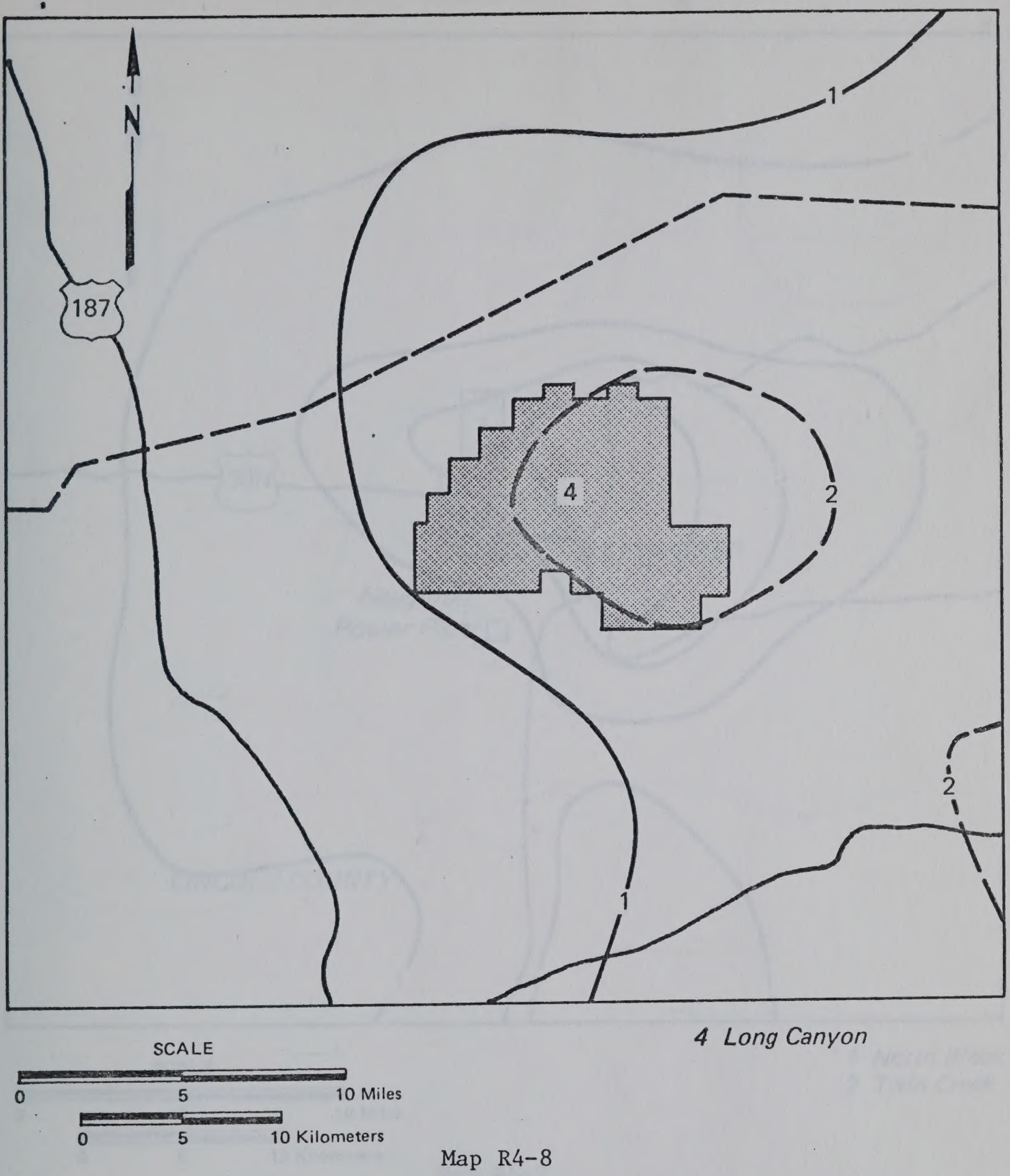
Map R4-6

1985 Predicted Annual Average SP Concentrations ($\mu g/m^3$)
Attributable to the Proposed Action Mines Alone


N
Bridger Power Plant
POINT OF ROCKS
80
3
5
7
9
11
5
1
1
5 Black Butte
SCALE
0
5
10 Miles
0
5
10 Kilometers

Map R4-7

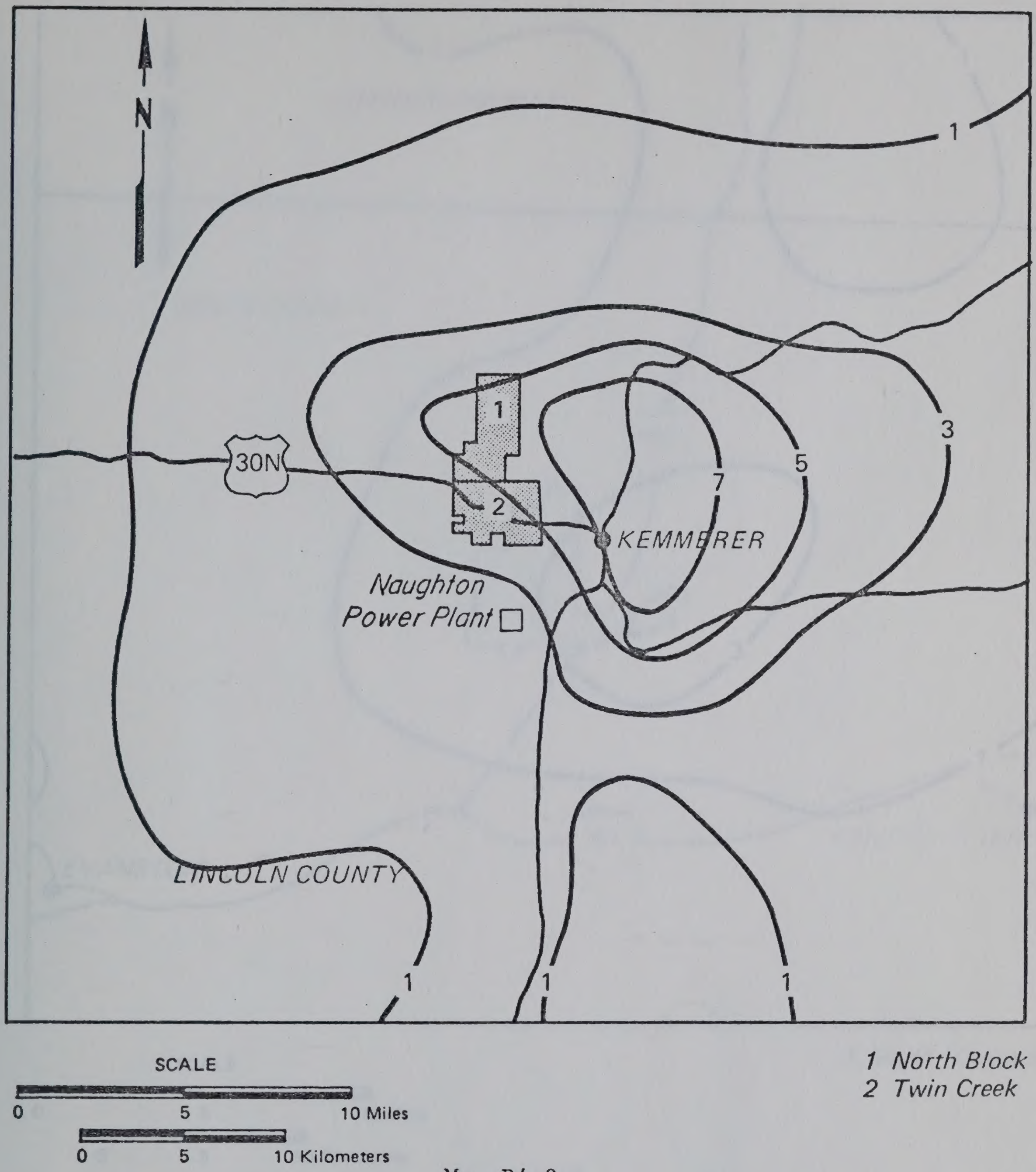
Black Butte 1985 Subregional Annual Average SP Concentrations ($\mu g/m^3$)
Attributable to the Proposed Action Mines Alone


N
187
1
1
2
2
4
4 Long Canyon
SCALE
0
5
10 Miles
0
5
10 Kilometers

Map R4-8

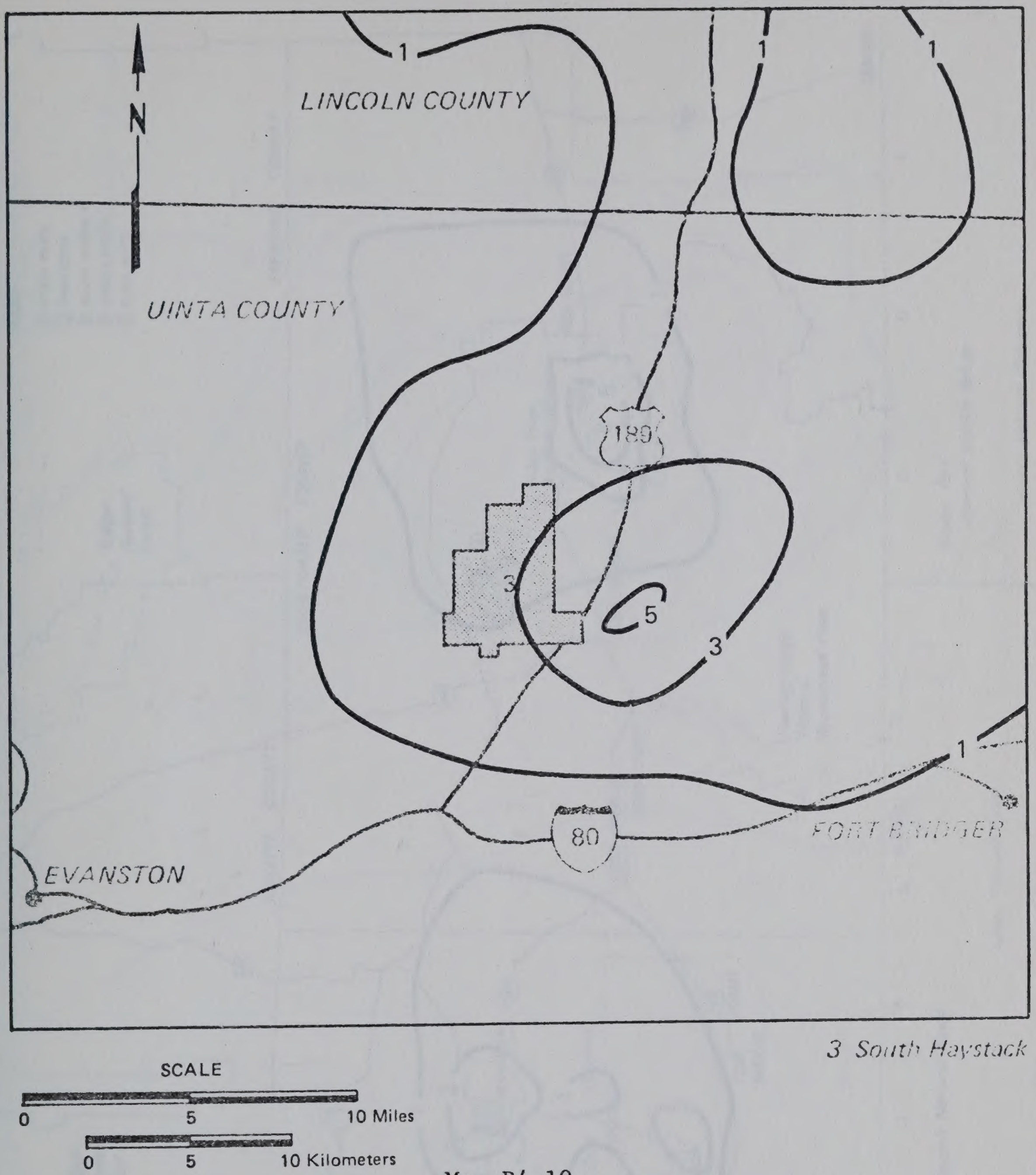
Long Canyon 1985 Subregional Annual Average SP Concentrations ($\mu g/m^3$)
Attributable to the Proposed Action Mines Alone

801141
803333


N
30N
1
3
5
7
KEMMERER
Naughton
Power Plant
LINCOLN COUNTY
1
1
1
1
2
SCALE
0
5
10 Miles
0
5
10 Kilometers
1 North Block
2 Twin Creek

Map R4-9

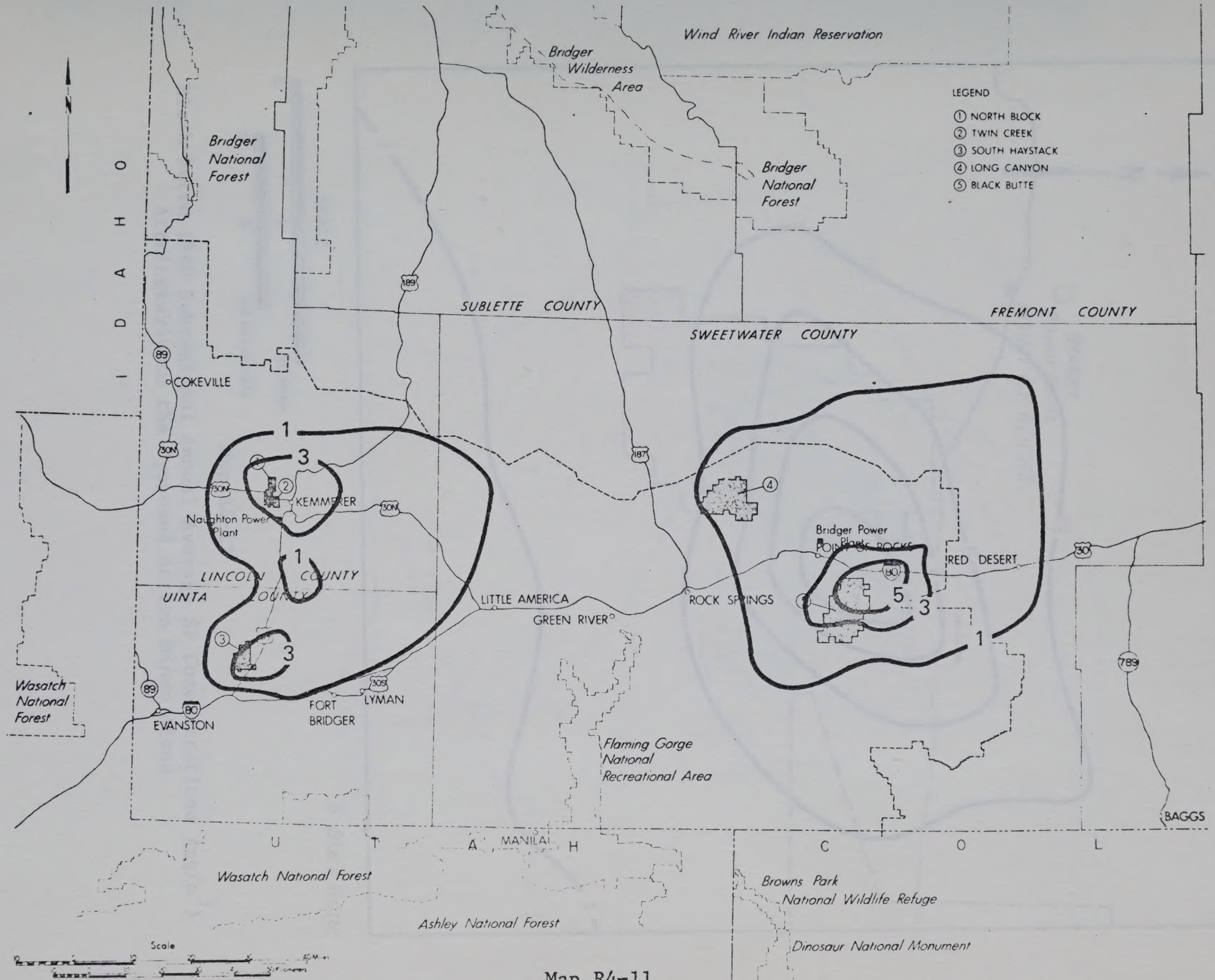
North Block - Twin Creek 1985 Subregional Annual Average SP Concentrations (μg/m^3)
Attributable to the Proposed Action Mines Alone


N
1
1
1
LINCOLN COUNTY
UINTA COUNTY
189
3
5
3
1
80
EVANSTON
FORT BRIDGER
3 South Haystack
SCALE
0
5
10 Miles
0
5
10 Kilometers

Map R4-10

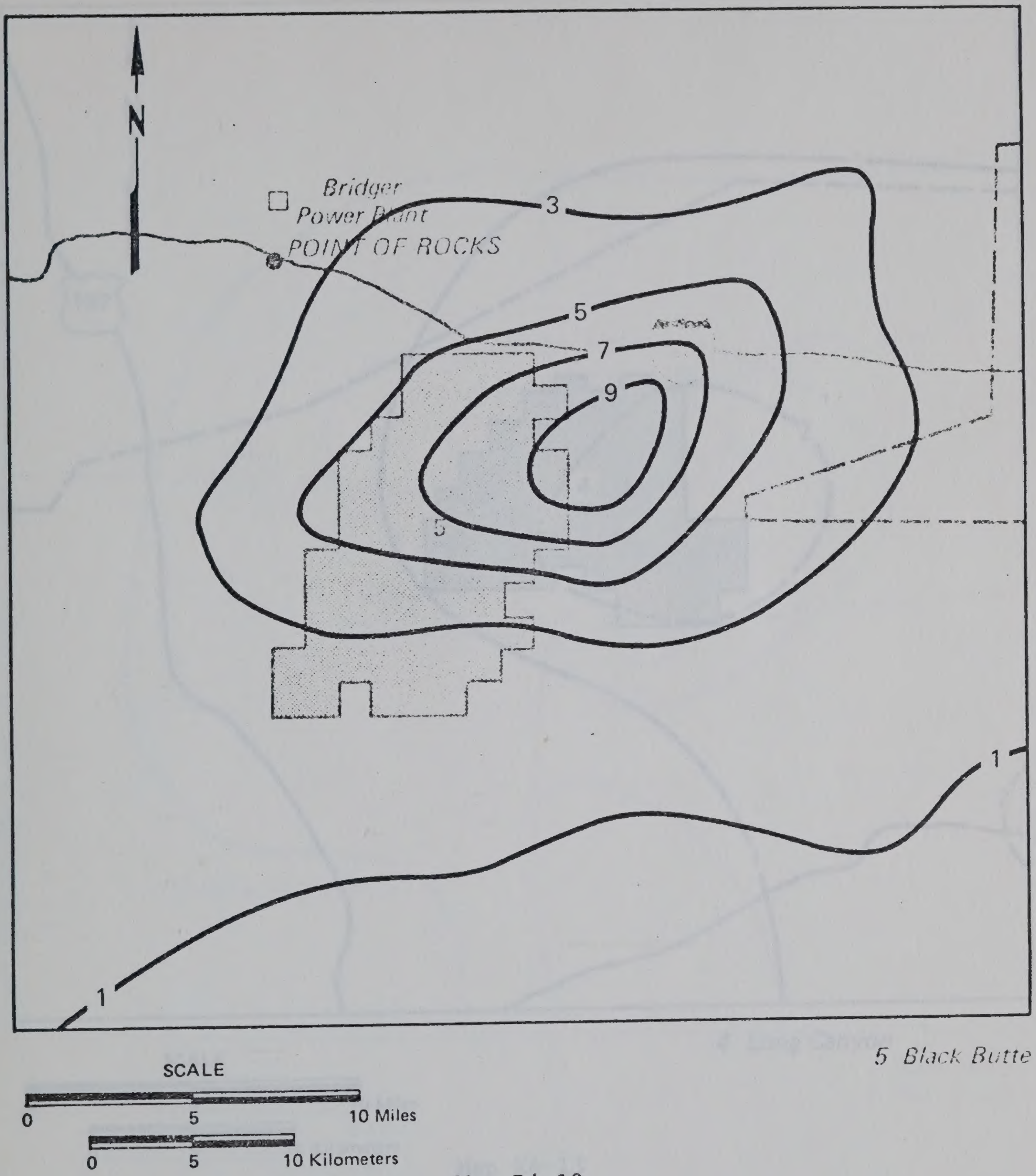
South Haystack 1985 Subregional Annual Average SP Concentrations ($\mu g/m^3$) Attributable to the Proposed Action Mines Alone

803281
803284


Wind River Indian Reservation
Bridger Wilderness Area
Bridger National Forest
Bridger National Forest
LEGEND
① NORTH BLOCK
② TWIN CREEK
③ SOUTH HAYSTACK
④ LONG CANYON
⑤ BLACK BUTTE
I D A H O
SUBLETTE COUNTY
FREMONT COUNTY
SWEETWATER COUNTY
189
89
COKEVILLE
30N
KEMMERER
Naughton Power Plant
LINCOLN COUNTY
UINTA COUNTY
187
LITTLE AMERICA
GREEN RIVER
ROCK SPRINGS
Bridger Power Plant
POINT OF ROCKS
RED DESERT
80
30
789
Wasatch National Forest
89
80
EVANSTON
FORT BRIDGER
30S
LYMAN
Flaming Gorge National Recreational Area
BAGGS
U T A H
MANILA
C O L
Wasatch National Forest
Ashley National Forest
Browns Park National Wildlife Refuge
Dinosaur National Monument
1
3
1
3
1
3
5
Scale
40 Miles
Kilometers

Map R4-11

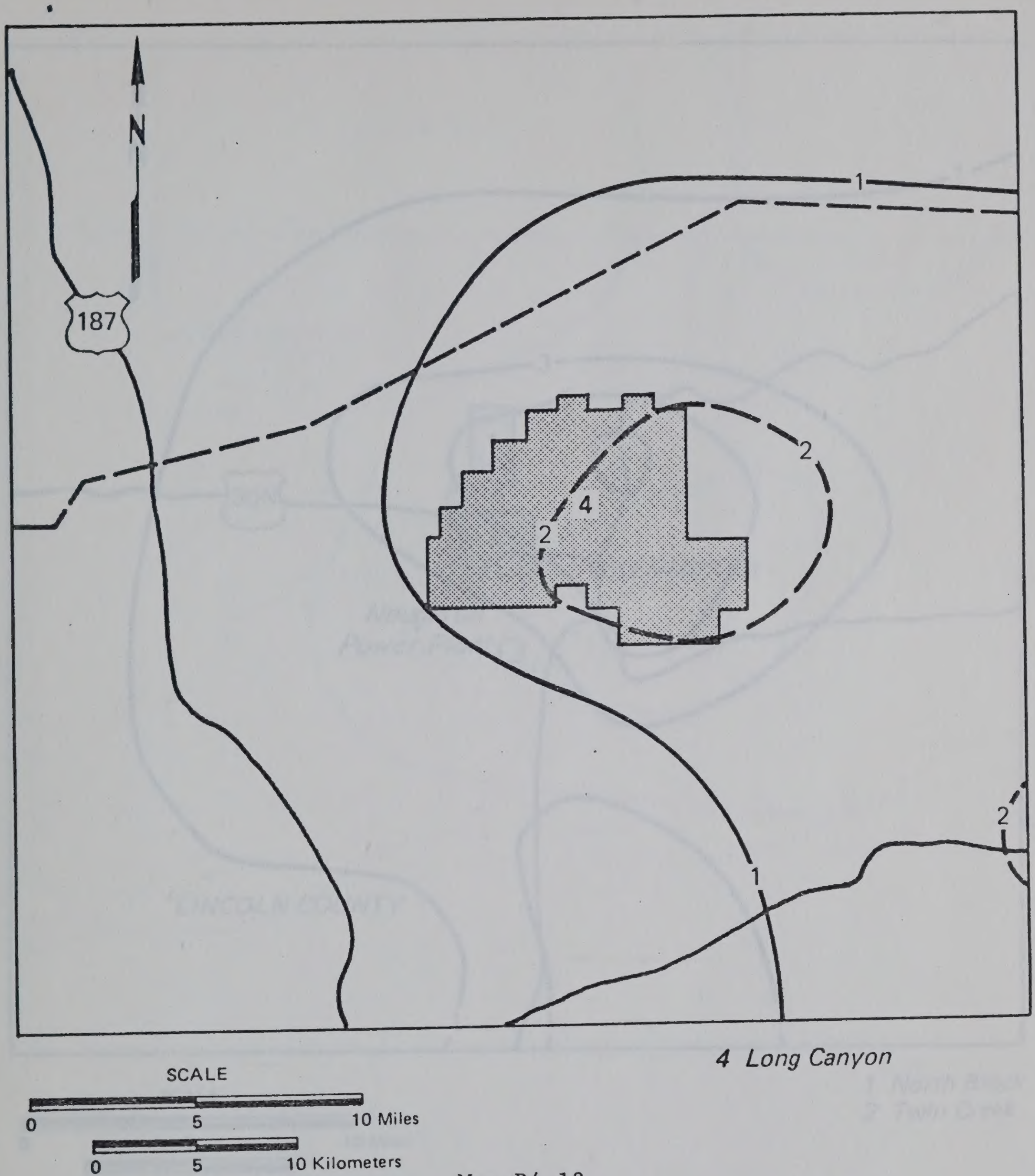
1990 Predicted Annual Average SP Concentrations ($\mu g/m^3$)
Attributable to the Proposed Action Mines Alone


N
Bridger Power Plant
POINT OF ROCKS
3
5
7
9
1
1
5
5 Black Butte
SCALE
0
5
10 Miles
0
5
10 Kilometers

Map R4-12

Black Butte 1990 Subregional Annual Average SP Concnetrations ($\mu g/m^3$) Attributable to the Proposed Action Mines Alone

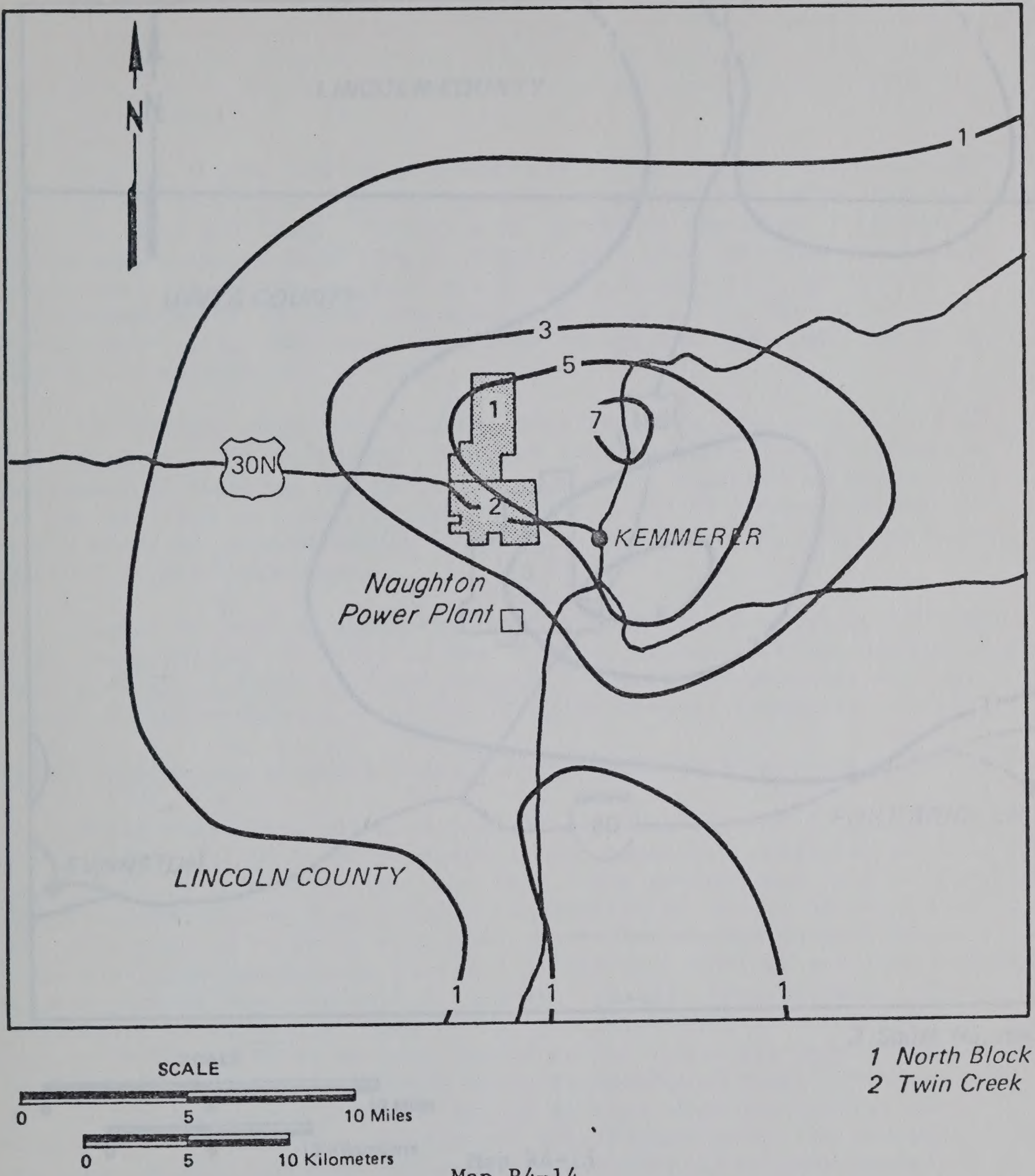
801143
803239


N
187
1
2
4
2
1
2
4 Long Canyon
SCALE
0
5
10 Miles
0
5
10 Kilometers

Map R4-13

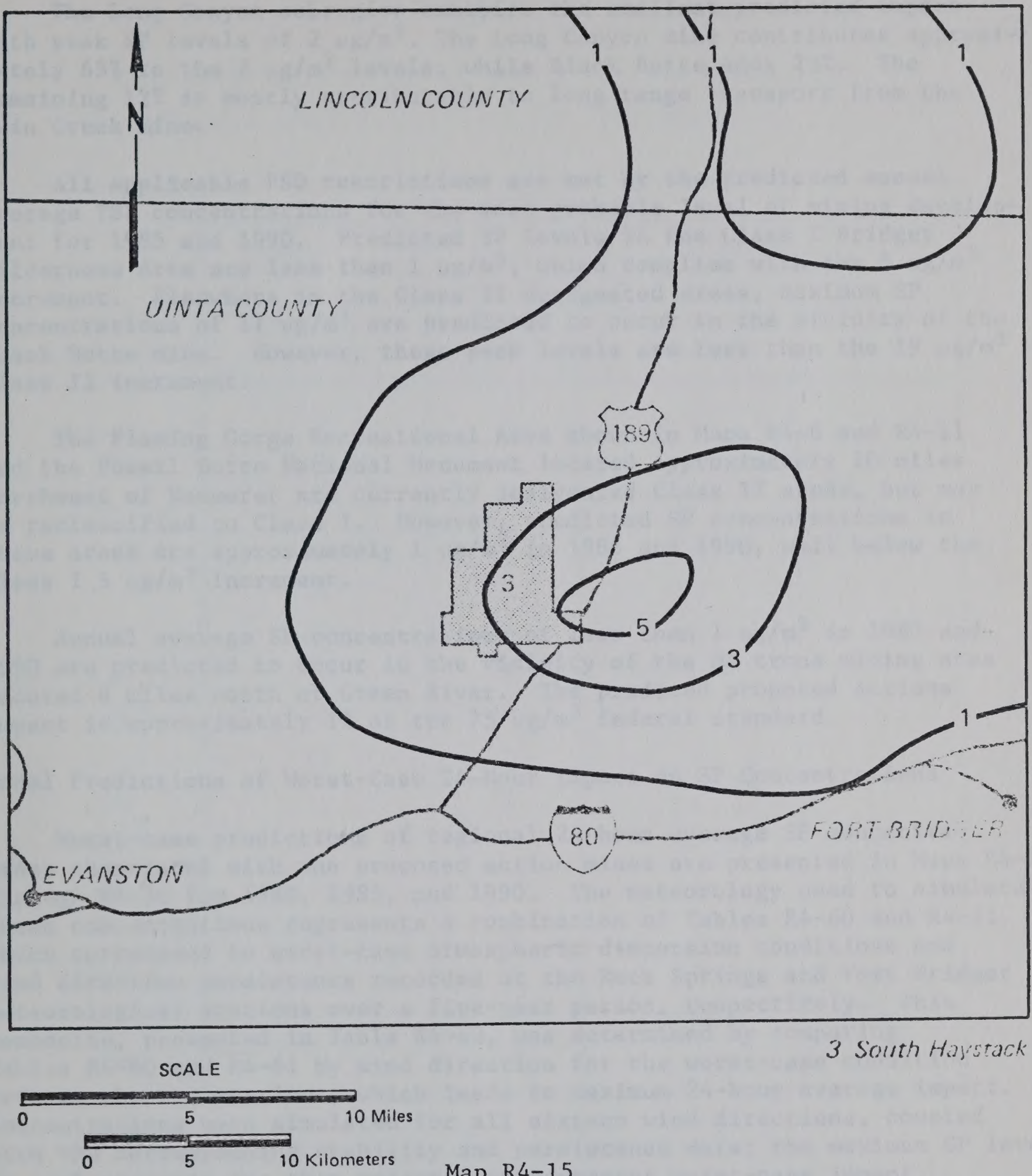
Long Canyon 1990 Subregional Annual Average SP Concentrations ($\mu g/m^3$)
Attributable to the Proposed Action Mines Alone

801141
803334


N
1
3
5
7
1
2
30N
KEMMERER
Naughton Power Plant
LINCOLN COUNTY
1
1
1
SCALE
0
5
10 Miles
0
5
10 Kilometers
1 North Block
2 Twin Creek

Map R4-14

North Block - Twin Creek 1990 Subregional Annual Average SP Concentrations ($\mu g/m^3$) Attributable to the Proposed Action Mines Alone


LINCOLN COUNTY
UINTA COUNTY
N
1
1
1
189
3
5
3
1
80
FORT BRIDGER
EVANSTON
3 South Haystack
SCALE
0
5
10 Miles
0
5
10 Kilometers

Map R4-15

South Haystack 1990 Subregional Annual Average SP Concentrations ($\mu g/m^3$) Attributable to the Proposed Action Mines Alone

The Long Canyon subregion exhibits the smallest predicted impact with peak SP levels of 2 μg/m^3. The Long Canyon mine contributes approximately 65% to the 2 μg/m^3 levels; while Black Butte adds 23%. The remaining 12% is mostly attributable to long range transport from the Twin Creek mine.

All applicable PSD restrictions are met by the predicted annual average TSP concentrations for the most probable level of mining development for 1985 and 1990. Predicted SP levels in the Class I Bridger Wilderness Area are less than 1 μg/m^3, which complies with the 5 μg/m^3 increment. Elsewhere in the Class II designated areas, maximum SP concentrations of 11 μg/m^3 are predicted to occur in the vicinity of the Black Butte mine. However, these peak levels are less than the 19 μg/m^3 Class II increment.

The Flaming Gorge Recreational Area shown in Maps R4-6 and R4-11 and the Fossil Butte National Monument located approximately 10 miles northwest of Kemmerer are currently designated Class II areas, but may be reclassified to Class I. However, predicted SP concentrations in these areas are approximately 1 μg/m^3 in 1985 and 1990, well below the Class I 5 μg/m^3 increment.

Annual average SP concentrations of less than 1 μg/m^3 in 1985 and 1990 are predicted to occur in the vicinity of the NA trona mining area located 6 miles north of Green River. The prediced proposed actions impact is approximately 1% of the 75 μg/m^3 federal standard.

Model Predictions of Worst-Case 24-Hour Impact on SP Concentrations

Worst-case predictions of regional 24-hour average SP concentrations associated with the proposed action mines are presented in Maps R4-16 through R4-30 for 1980, 1985, and 1990. The meteorology used to simulate these concentrations represents a combination of Tables R4-60 and R4-61, which correspond to worst-case atmospheric dispersion conditions and wind direction persistence recorded at the Rock Springs and Fort Bridger meteorological stations over a five-year period, respectively. This composite, presented in Table R4-63, was determined by comparing Tables R4-60 and R4-61 by wind direction for the worst-case condition between the two stations, which leads to maximum 24-hour average impact. Concentrations were simulated for all sixteen wind directions, coupled with the corresponding stability and persistence data; the maximum SP level at each receptor was then selected to represent worst-case impact. Consequently, it is important to note that the 24-hour averages shown throughout the ES region cannot occur simultaneously. In fact, it is somewhat unrealistic to evaluate worst-case 24-hour average impact on a regional scale, since the meteorological conditions leading to maximum SP levels at one location will not pertain to all receptor locations. The wind direction determining peak SP concentrations depends on the

TABLE R4-63

COMPOSITE* METEOROLOGICAL CONDITIONS FOR WORST-CASE 24-HOUR AVERAGE IMPACT ON TSP CONCENTRATIONS

Wind Direction	Atmospheric Stability			
	Stable		Neutral	
	Persistence (hours)	Wind Speed (mph)	Persistence (hours)	Wind Speed (mph)
N	6	4	–	–
NNE	4	4	–	–
NE	–	–	24	10
ENE	12	4	1	4
E	11	6	–	–
ESE	12	6	1	6
SE	7	4	–	–
SSE	6	6	–	–
S	13	4	–	–
SSW	5	4	–	–
SW	–	–	24	10
WSW	12	4	8	4
W	14	6	1	6
WNW	12	4	1	4
NW	12	4	4	4
NNW	3	4	–	–

*Determined from Rock Springs and Fort Bridger data.

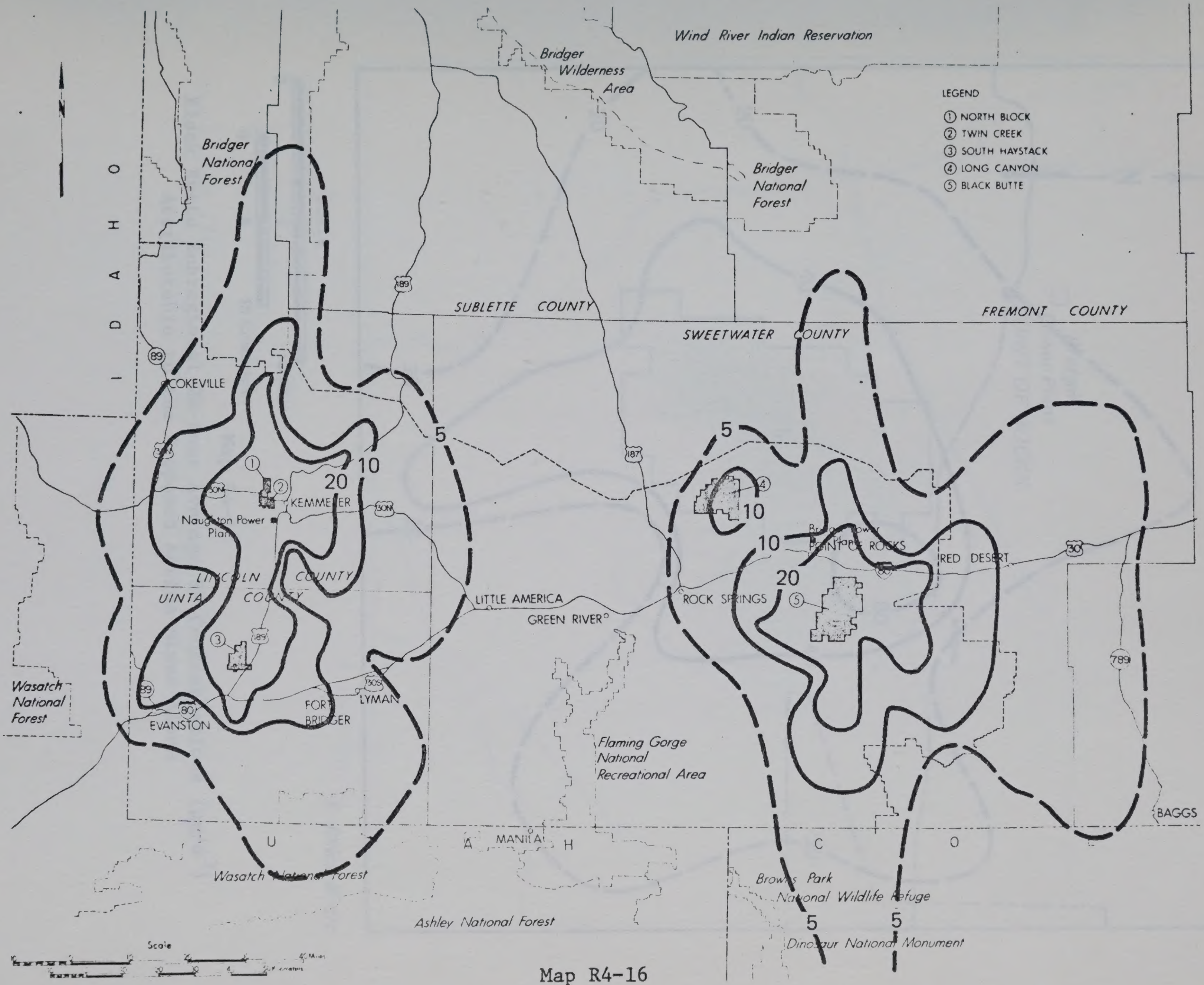
location of each receptor relative to the mine sites. In short, simulated 24-hour average concentrations depicted in Maps R4-16 through R4-30 are indicative of absolute worst-case impacts corresponding to a composite of maximum model predictions for all wind directions; such SP levels cannot occur simultaneously throughout the region, but the assumption is made that the predicted values at individual receptors could occur at least once per year.

Model Predictions of 24-Hour Average Impact on SP Concentrations for 1980

Maps R4-16 through R4-20 present simulated SP concentrations for 1980 due to the impact from the proposed action mines alone. Regionally, depicted SP levels range from 5 to approximately 120 μg/m^3, with the highest predictions occurring close to the mining activities. In the Rock Springs area, worst-case predicted SP levels are associated mostly with emissions from the Black Butte mine. Long Canyon is the only other operational mine in 1980 near the Rock Springs area, and its emissions are less than 8% of Black Butte's. The elongated portions of the isopleths in the eastern portion of southwest Wyoming are associated with the wind direction that lines up the Black Butte mine with such receptors. The only significant influence resulting from Long Canyon is to receptors located very close (within 3 to 5 miles) to the Long Canyon mine. Illustrations of simulated SP concentrations close to the Black Butte and Long Canyon mines are presented in Maps R4-17 and R4-18, respectively. Peak predicted levels of approximately 20 μg/m^3 are located slightly south of the Long Canyon mine. These concentrations are associated with a northerly wind flow. Concentrations of 20 μg/m^3 are also predicted to occur 12 miles southeast of Long Canyon. These levels result from an east-southeast wind direction dispersing pollutant levels emanating from the Black Butte mine. Approximately 2.5 miles north-northeast of Black Butte (Map R4-17) maximum predictions peak at 80 μg/m^3, one of the highest levels simulated throughout the ES region. These levels correspond to a west-southwest wind flow. Elsewhere within the Black Butte subregion, predicted concentrations ranging from 4 to 80 μg/m^3 are generally dominated by dispersion of Black Butte's emissions.

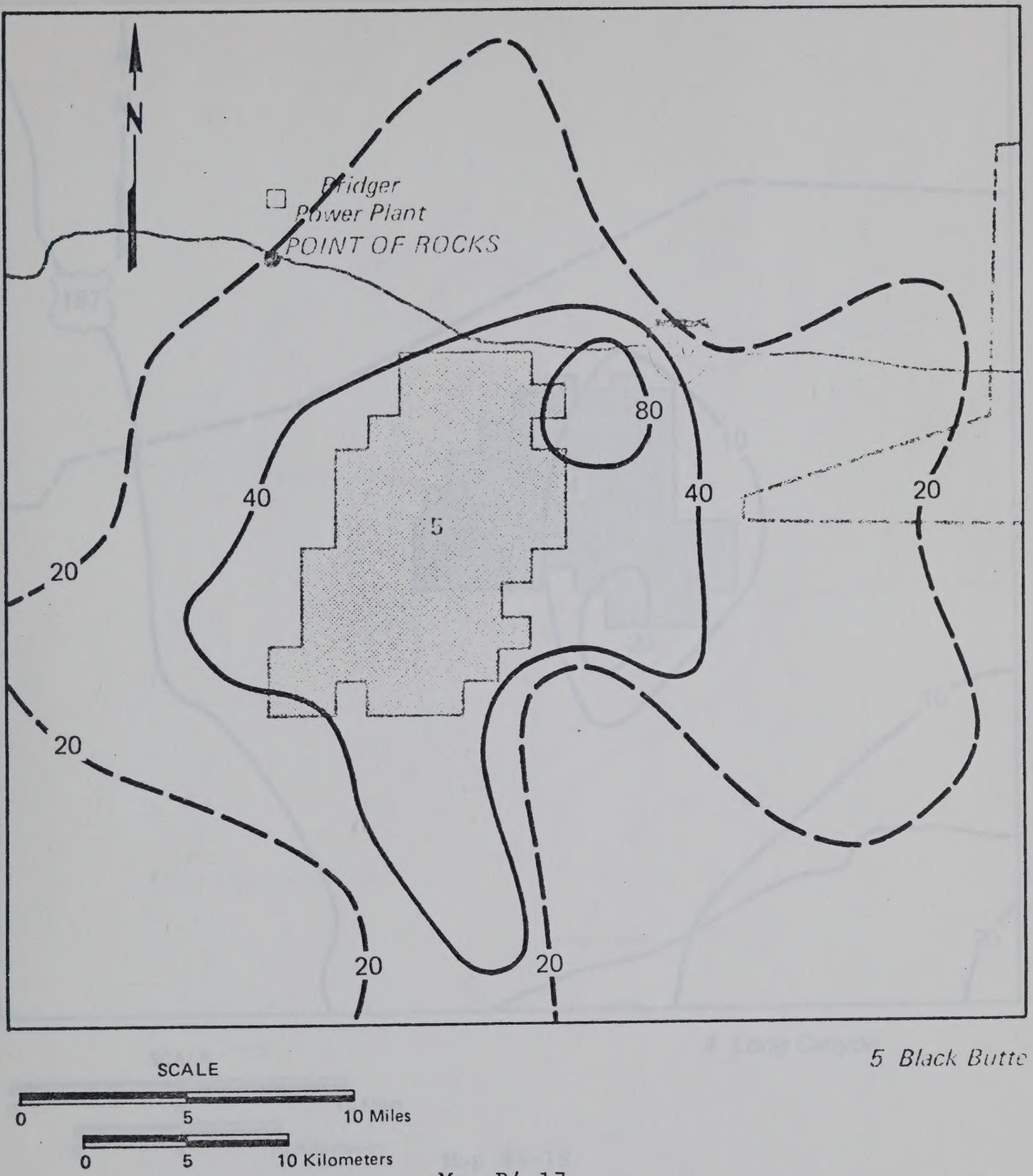
In the western half of the ES region, Map R4-16 indicates significant impact resulting from north and south wind flow. Because of the relative locations of North Block, Twin Creek, and South Haystack, both northerly and southerly winds result in the interaction of pollutants dispersing from all three surface mines. Such interaction is seen to affect simulated SP concentrations approximately 60 miles north and south of Kemmerer. Interaction between the South Haystack mine and the North Block-Twin Creek mining subregion is small or nonexistent under easterly or westerly wind flow. In general, predicted levels east or west of South Haystack (within about 40 miles) are dominated by fugitive

803281
803285


Wind River Indian Reservation
Bridger Wilderness Area
Bridger National Forest
Bridger National Forest
LEGEND
① NORTH BLOCK
② TWIN CREEK
③ SOUTH HAYSTACK
④ LONG CANYON
⑤ BLACK BUTTE
IDAHO
SUBLETTE COUNTY
SWEETWATER COUNTY
FREMONT COUNTY
COKEVILLE
KEMMERER
Naughton Power Plant
LINCOLN COUNTY
UINTA COUNTY
EVANSTON
FORT BRIDGER
LYMAN
LITTLE AMERICA
GREEN RIVER
ROCK SPRINGS
Bridger Power Plant
POINT OF ROCKS
RED DESERT
BAGGS
Wasatch National Forest
Wasatch National Forest
Ashley National Forest
Flaming Gorge National Recreational Area
MANILA
UTAH
COLO
Browns Park National Wildlife Refuge
Dinosaur National Monument
5
10
20
5
10
10
20
5
5
89
189
30N
187
80
30S
30
789
Scale

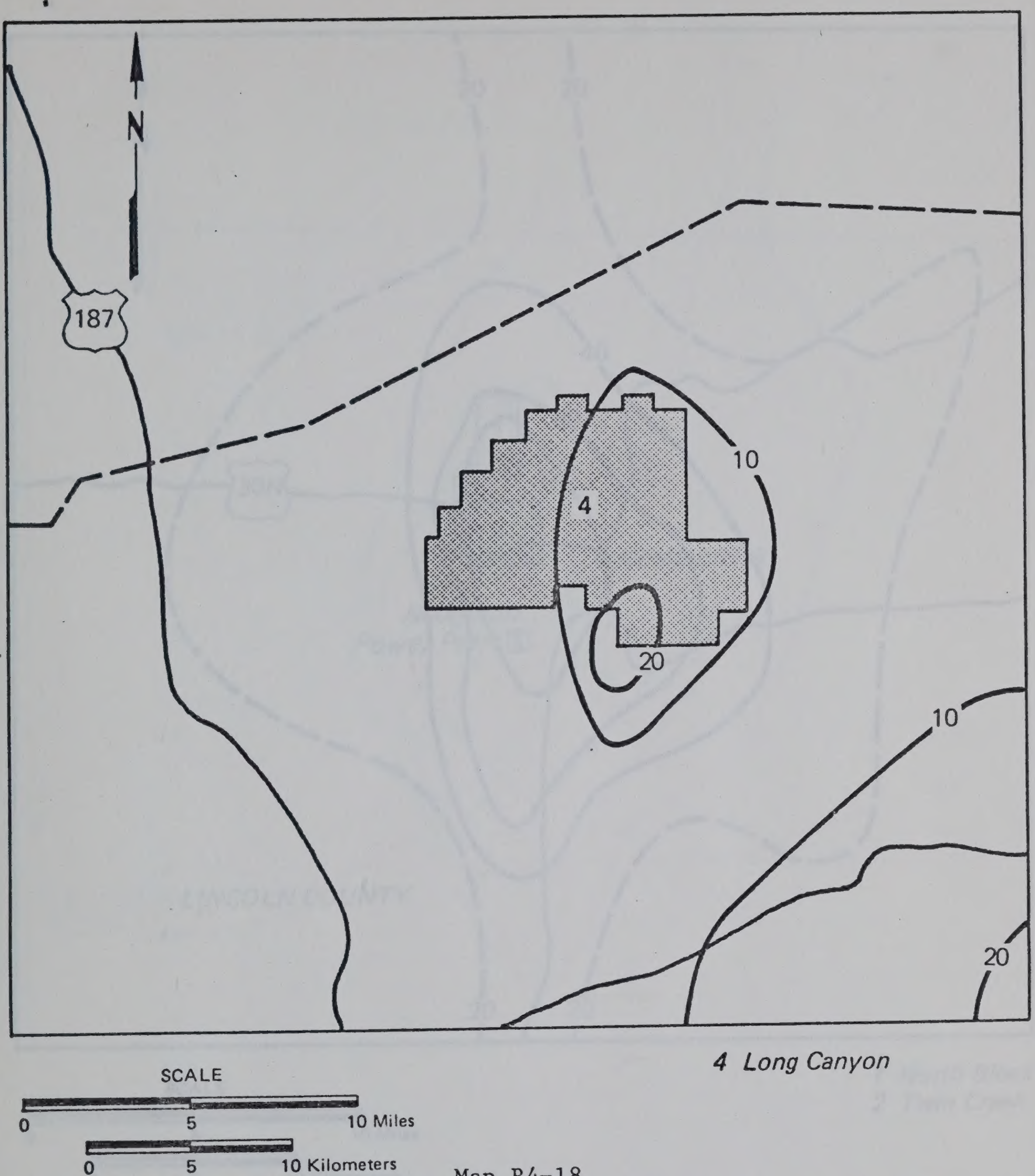
Map R4-16

1980 Predicted 24-Hour Average SP Concentrations ($\mu g/m^3$)
Attributable to the Proposed Action Mines Alone


N
Bridger Power Plant
POINT OF ROCKS
80
40
40
20
20
20
20
20
20
5
5 Black Butte
SCALE
0
5
10 Miles
0
5
10 Kilometers

Map R4-17

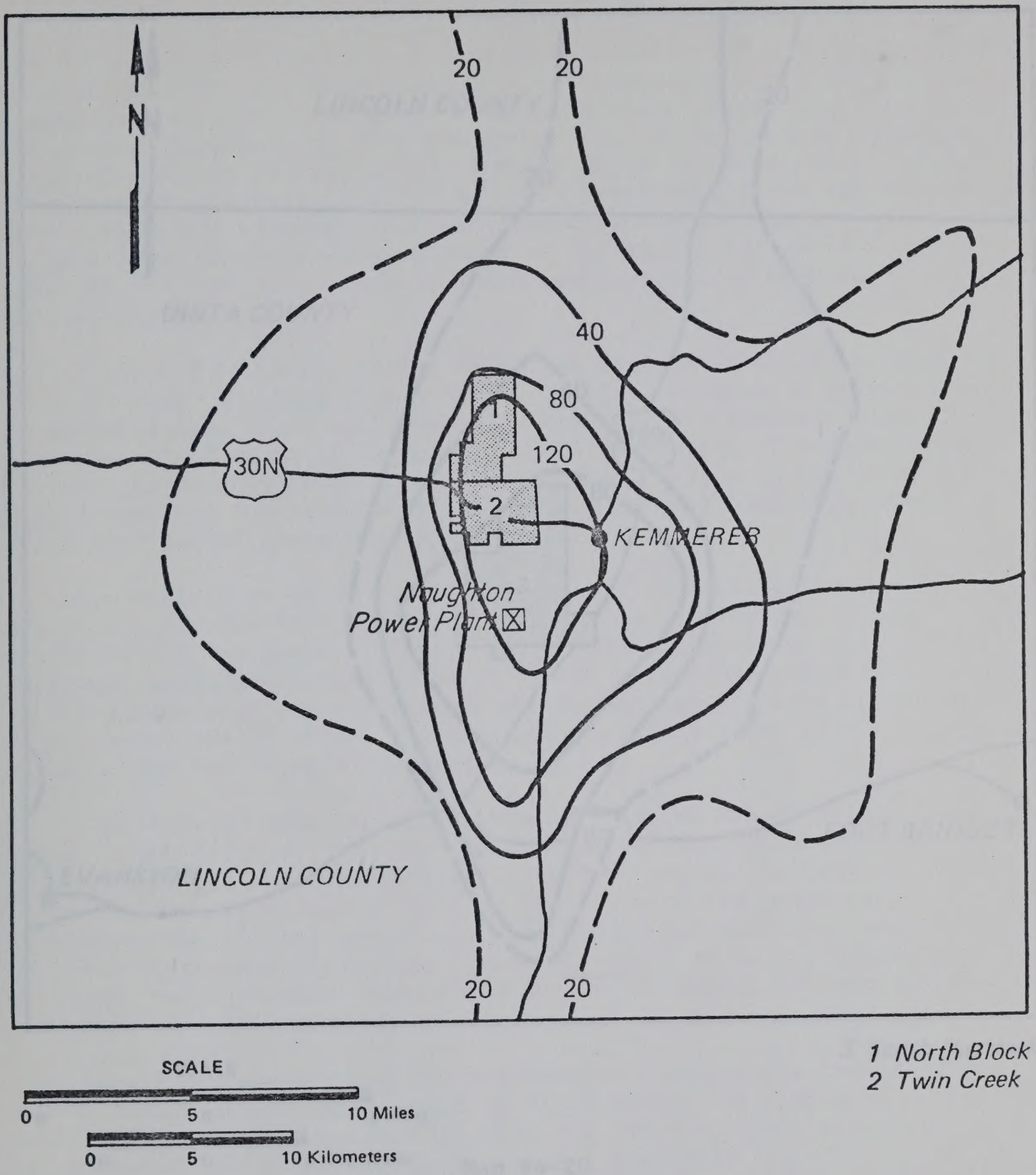
Black Butte Subregional 24-Hour Average SP Concentrations ($\mu g/m^3$) Attributable to the Proposed Action Mines Alone


N
187
10
4
20
10
20
4 Long Canyon
SCALE
0
5
10 Miles
0
5
10 Kilometers

Map R4-18

Long Canyon 1980 Subregional 24-Hour Average SP Concentrations (μg/m^3)
Attributable to the Proposed Action Mines Alone

801141
803335

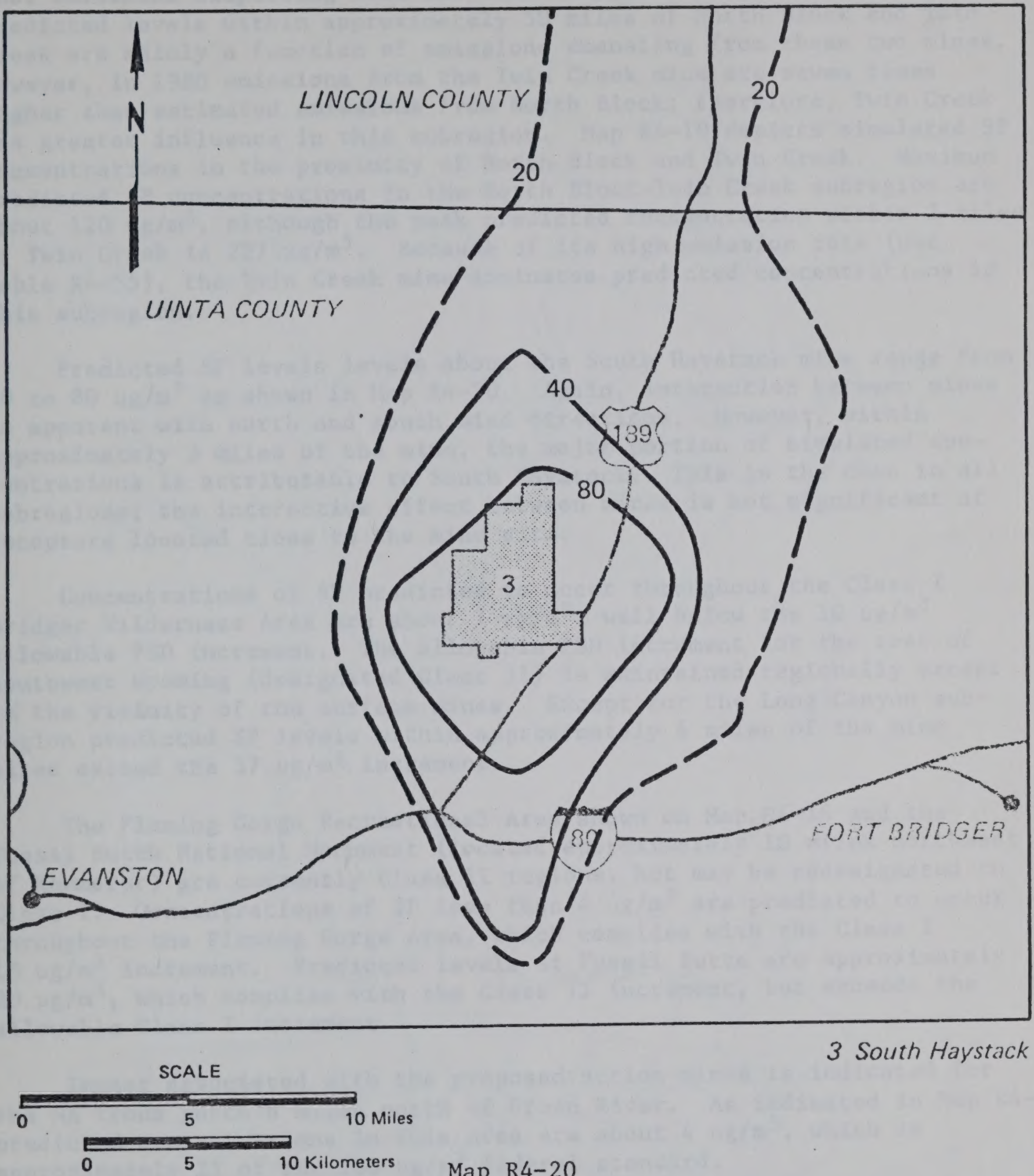

N
20
20
40
80
120
30N
1
2
KEMMERER
Naughton
Power Plant ☒
LINCOLN COUNTY
20
20
SCALE
0
5
10 Miles
0
5
10 Kilometers
1 North Block
2 Twin Creek

X = Maximum Predicted Concentration = 227 μg/m^3

Map R4-19

North Block - Twin Creek 1980 Subregional 24-Hour Average SP Concentrations (μg/m^3) Attributable to the Proposed Action Mines Alone

801147
803257


N
LINCOLN COUNTY
UINTA COUNTY
20
20
20
40
80
3
89
89
FORT BRIDGER
EVANSTON
3 South Haystack
SCALE
0
5
10 Miles
0
5
10 Kilometers

Map R4-20

South Haystack 1980 Subregional 24-Hour SP Concentrations ($\mu g/m^3$)
Attributable to the Proposed Action Mines Alone

801145
803279

dust emissions dispersing from the South Haystack mine. Similarly, predicted levels within approximately 50 miles of North Block and Twin Creek are mainly a function of emissions emanating from these two mines. However, in 1980 emissions from the Twin Creek mine are seven times higher than estimated emissions from North Block; therefore, Twin Creek has greater influence in this subregion. Map R4-19 depicts simulated SP concentrations in the proximity of North Block and Twin Creek. Maximum predicted SP concentrations in the North Block-Twin Creek subregion are about 120 $\mu g/m^3$, although the peak predicted concentration within 2 miles of Twin Creek is 227 $\mu g/m^3$. Because of its high emission rate (see Table R4-55), the Twin Creek mine dominates predicted concentrations in this subregion.

Predicted SP levels levels about the South Haystack mine range from 20 to 80 $\mu g/m^3$ as shown in Map R4-20. Again, interaction between mines is apparent with north and south wind directions. However, within approximately 3 miles of the mine, the major portion of simulated concentrations is attributable to South Haystack. This is the case in all subregions; the interactive effect between mines is not significant at receptors located close to the mine site.

Concentrations of SP predicted to occur throughout the Class I Bridger Wilderness Area are about 1 $\mu g/m^3$, well below the 10 $\mu g/m^3$ allowable PSD increment. The allowable PSD increment for the rest of southwest Wyoming (designated Class II) is maintained regionally except in the vicinity of the surface mines. Except for the Long Canyon subregion predicted SP levels within approximately 6 miles of the mine sites exceed the 37 $\mu g/m^3$ increment.

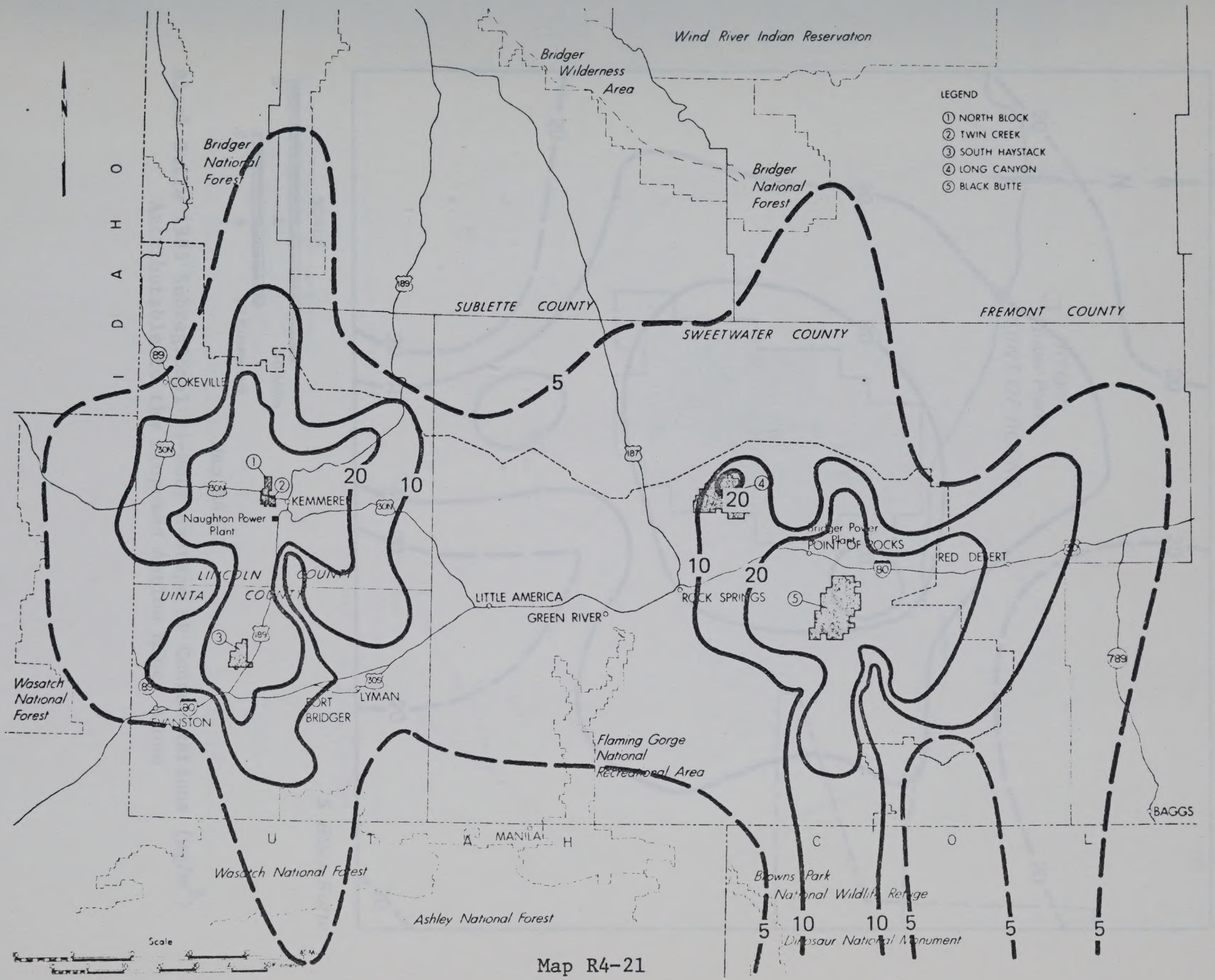
The Flaming Gorge Recreational Area shown on Map R4-16 and the Fossil Butte National Monument (located approximately 10 miles northwest of Kemmerer) are currently Class II regions, but may be redesignated to Class I. Concentrations of SP less than 4 $\mu g/m^3$ are predicted to occur throughout the Flaming Gorge Area, which complies with the Class I 10 $\mu g/m^3$ increment. Predicted levels at Fossil Butte are approximately 20 $\mu g/m^3$, which complies with the Class II increment, but exceeds the allowable Class I increment.

Impact associated with the proposed action mines is indicated for the NA trona patch 6 miles north of Green River. As indicated in Map R4-16, predicted concentrations in this area are about 4 $\mu g/m^3$, which is approximately 2% of the 260 $\mu g/m^3$ federal standard.

Model Predictions of 24-Hour Average Impact on SP Concentrations for 1985

Predicted SP impact from the proposed mine actions alone is depicted in Maps R4-21 through R4-25. Regionally, simulated SP levels range from

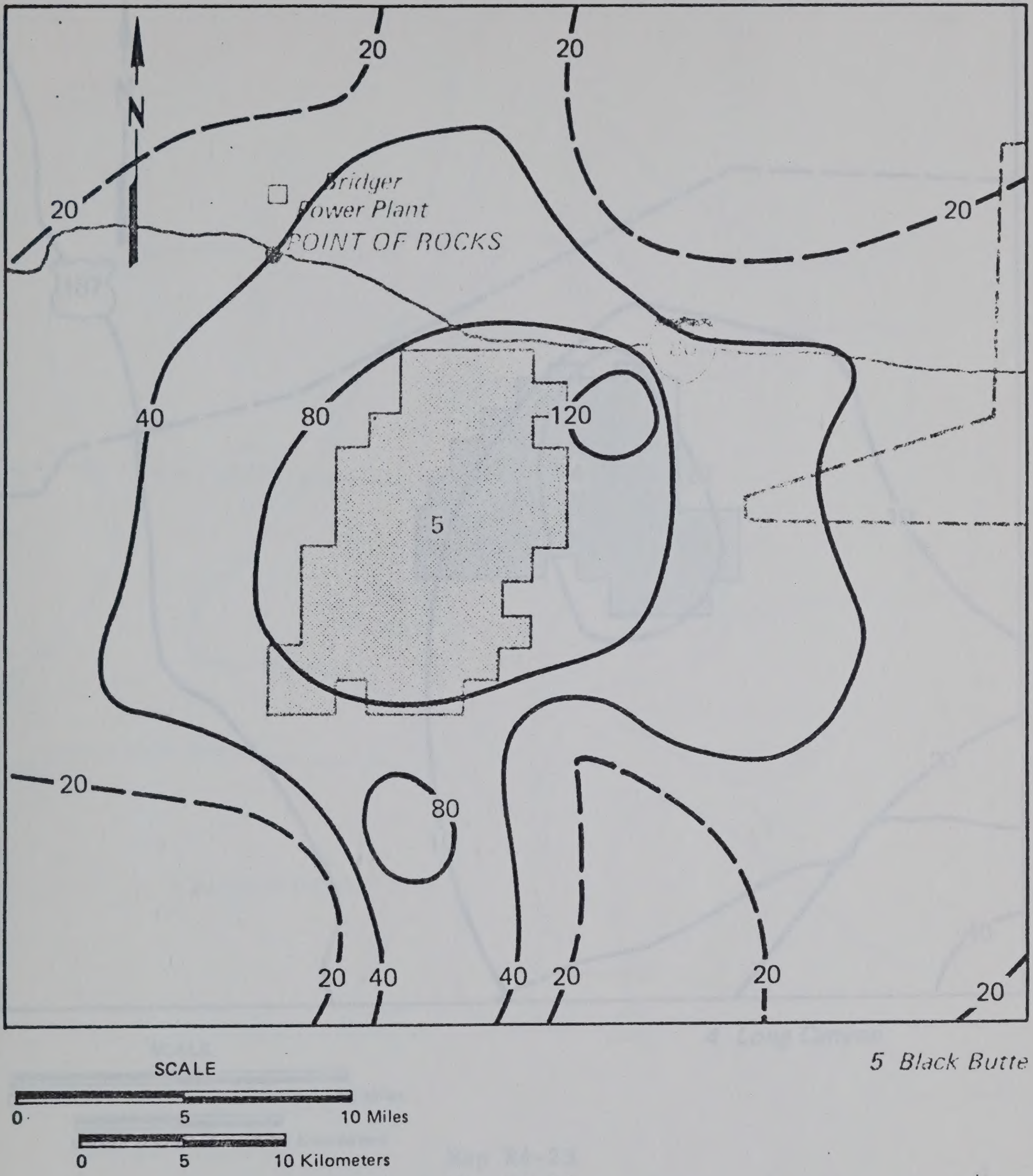
803281
803286



Wind River Indian Reservation
Bridger Wilderness Area
LEGEND
① NORTH BLOCK
② TWIN CREEK
③ SOUTH HAYSTACK
④ LONG CANYON
⑤ BLACK BUTTE
Bridger National Forest
Bridger National Forest
IDAHO
SUBLETTE COUNTY
FREMONT COUNTY
SWEETWATER COUNTY
COKEVILLE
KEMMERER
Naughton Power Plant
LINCOLN COUNTY
UINTA COUNTY
LITTLE AMERICA
GREEN RIVER
ROCK SPRINGS
Bridger Power Plant
POINT OF ROCKS
RED DESERT
EVANSTON
FORT BRIDGER
LYMAN
Wasatch National Forest
Flaming Gorge National Recreational Area
BAGGS
UTAH
COLO
MANILA
Wasatch National Forest
Ashley National Forest
Browns Park National Wildlife Refuge
Dinosaur National Monument
Scale
5
10
20
20
10
20
5
10
10
5
5
5

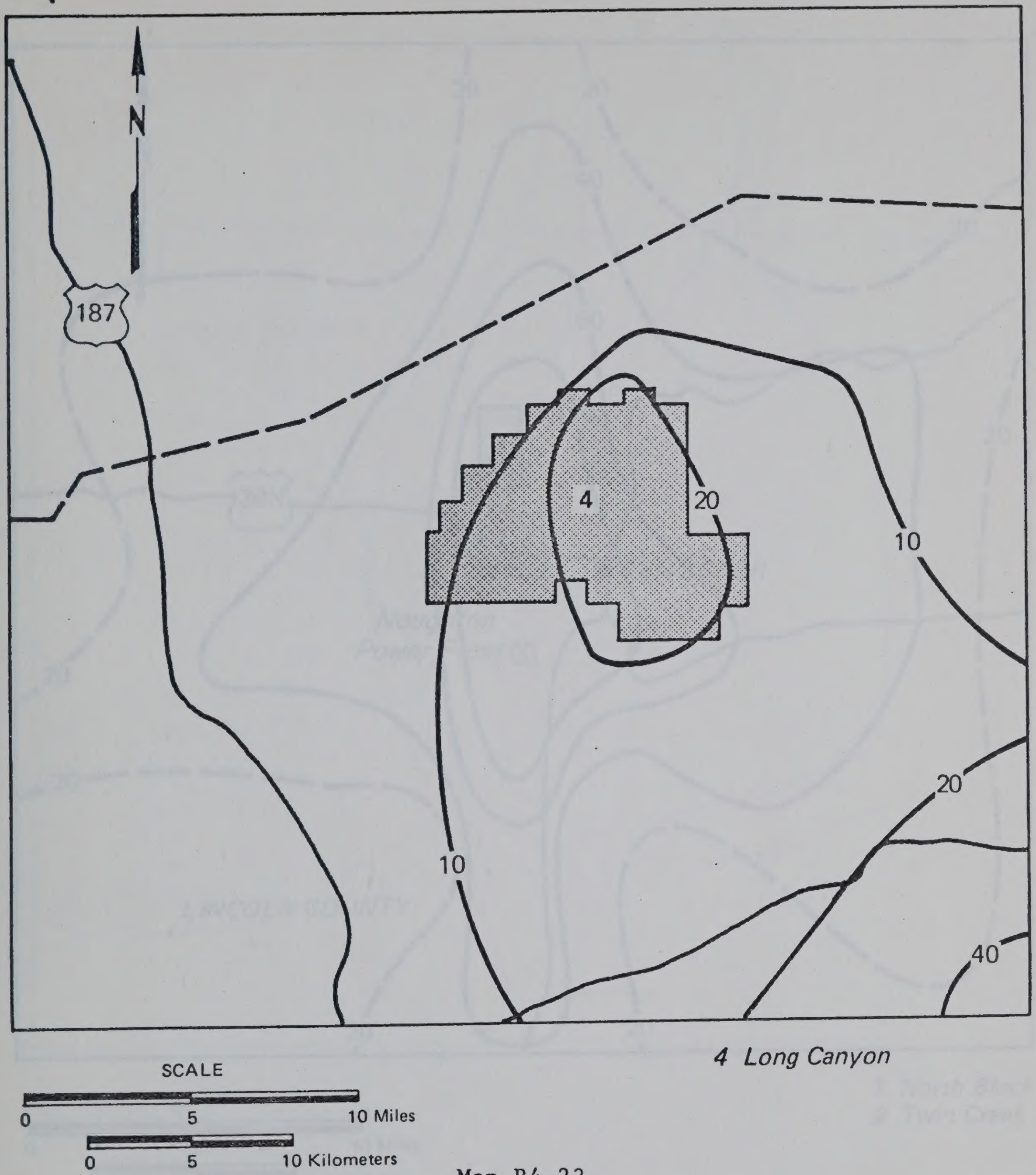
Map R4-21

1985 Predicted 24-Hour Average SP Concentrations ($\mu g/m^3$)
Attributable to the Proposed Action Mines Alone


N
20
20
20
20
Bridger Power Plant
POINT OF ROCKS
40
80
120
5
20
80
20
40
40
20
20
20
5 Black Butte
SCALE
0
5
10 Miles
0
5
10 Kilometers

Map R4-22

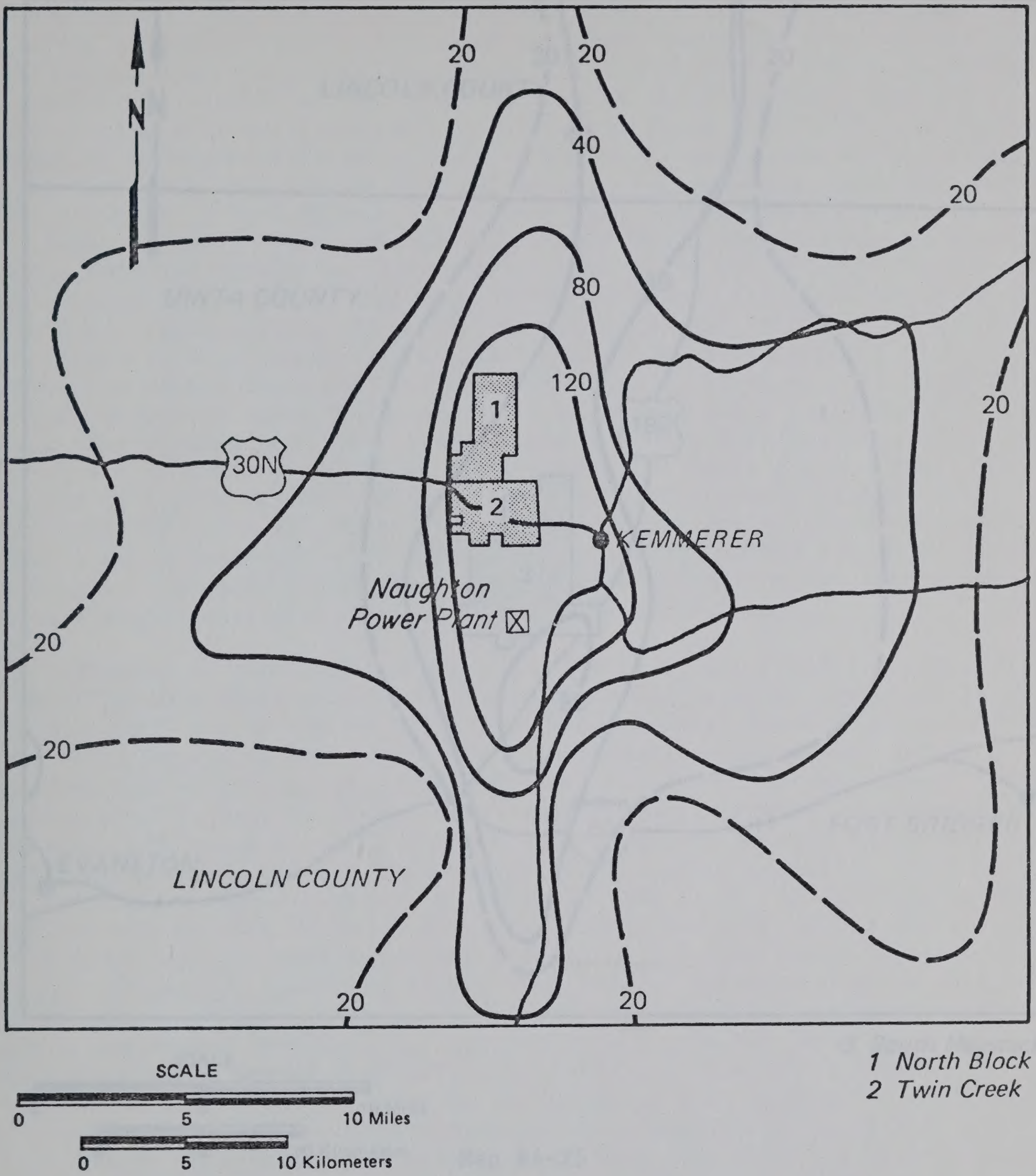
Black Butte 1985 Subregional 24-Hour Average SP Concentrations (µg/m^3)
Attributable to the Proposed Action Mines Alone


N
187
4
20
10
10
20
40
4 Long Canyon
SCALE
0
5
10 Miles
0
5
10 Kilometers

Map R4-23

Long Canyon 1985 Subregional 24-Hour Average SP Concentrations ($\mu g/m^3$) Attributable to the Proposed Action Mines Alone

801141
803336

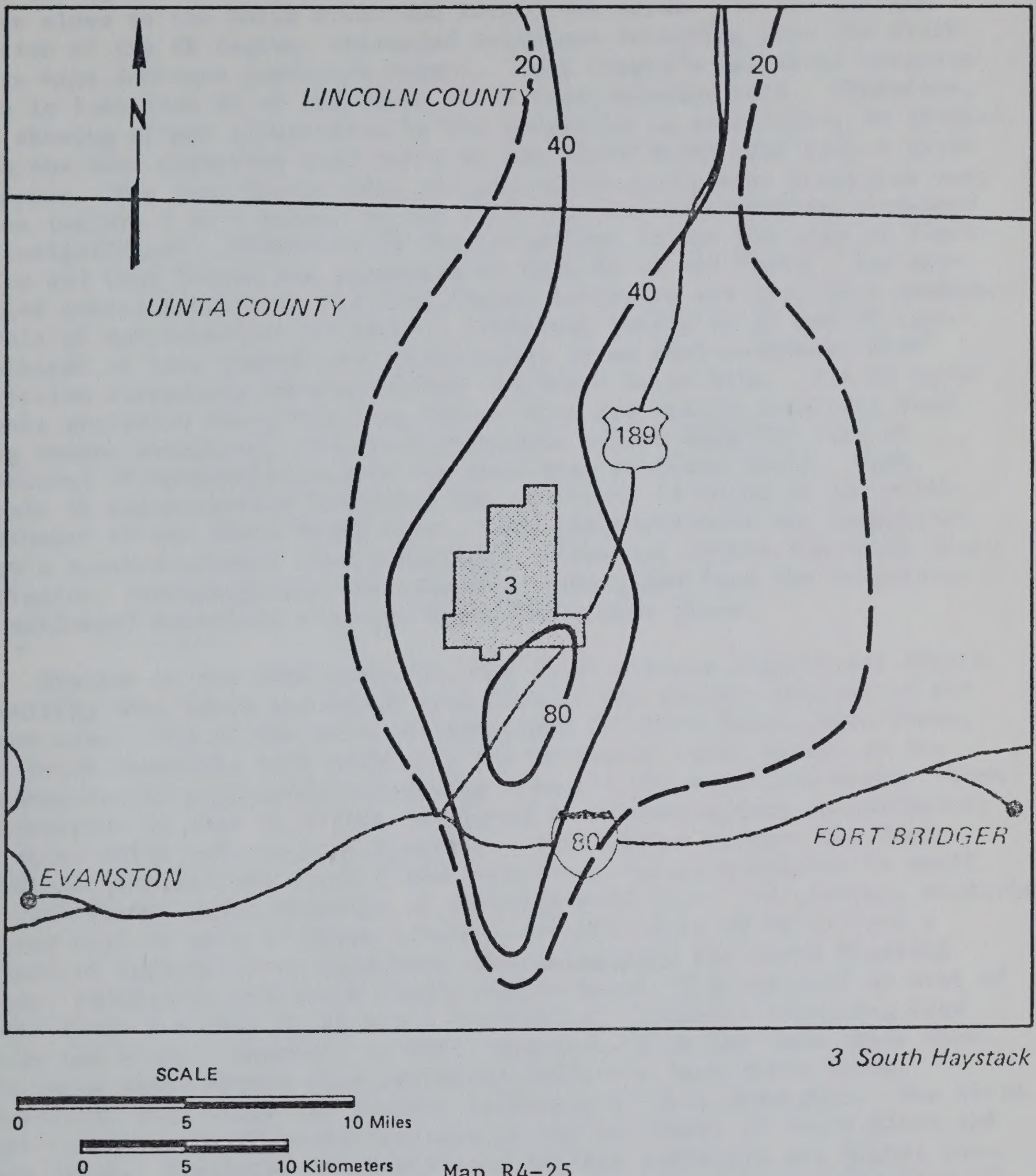

N
20
20
40
20
80
120
20
30N
1
2
KEMMERER
Naughton Power Plant
20
20
LINCOLN COUNTY
20
20
SCALE
0
5
10 Miles
0
5
10 Kilometers
1 North Block
2 Twin Creek

X = Maximum Predicted Concentration = 322 μg/m³

Map R4-24

North Block - Twin Creek 1985 Subregional 24-Hour Average SP Concentrations (μg/m³) Attributable to the Proposed Action Mines Alone

801147
803256


20
20
LINCOLN COUNTY
N
40
UINTA COUNTY
40
189
3
80
80
EVANSTON
FORT BRIDGER
3 South Haystack
SCALE
0
5
10 Miles
0
5
10 Kilometers

Map R4-25

South Haystack 1985 Subregional 24-Hour Average SP Concentrations ($\mu g/m^3$)
Attributable to the Proposed Action Mines Alone

5 to 120 $\mu g/m^3$, although somewhat higher concentrations are predicted to occur close to the North Block and Twin Creek mines. In the eastern portion of the ES region, estimated emissions emanating from the Black Butte mine dominate predicted impact. Long Canyon's estimated emission rate is less than 9% of the Black Butte mine emission rate. Therefore, the skewing effect illustrated by the isopleths is associated, in general, with the wind direction that lines up the Black Butte mine with a given receptor. The long Canyon mine influences concentrations predicted very close (within 3 to 5 miles) to the mine, but its contribution elsewhere is insignificant. Simulated SP concentrations in the vicinity of Black Butte and Long Canyon are presented in Maps R4-22 and R4-23. The predicted concentrations in the Long Canyon subregion are low, with maximum levels of approximately 20 $\mu g/m^3$. Predicted levels of 20 and 40 $\mu g/m^3$ southeast of Long Canyon are attributable to an east-southeast wind direction dispersing emissions from the Black Butte mine. The 20 $\mu g/m^3$ levels predicted about the Long Canyon mine are mostly resultant from Long Canyon emissions. Map R4-22 presents a more detailed view of simulated SP concentrations in the proximity of Black Butte. Peak levels of approximately 120 $\mu g/m^3$ are predicted to occur to the north-northeast of the Black Butte mine. Such concentrations are associated with a south-southwest wind direction. Elsewhere within the Black Butte subregion, concentrations are generally determined from the dispersion of estimated emissions from the Black Butte mine alone.

Similar to the 1980 analysis, Map R4-21 depicts significant impact resulting from north and south wind flow in the western portion of the study area. Due to the relative locations of North Block, Twin Creek, and South Haystack, both northerly and southerly winds result in the interaction of pollutants dispersing from all three surface mines. Such interaction is seen to affect simulated SP concentrations approximately 60 miles north and south of Kemmerer. Interaction between the South Haystack mine and the North Block-Twin Creek mining subregion is small or nonexistent under easterly or westerly wind flow. In general, predicted levels east or west of South Haystack (within about 40 miles) are a result of fugitive dust emissions dispersing from the South Haystack mine. Similarly, predicted levels within about 50 miles east or west of North Block and Twin Creek are a function of emissions emanating from these two mines. However, in 1985, emissions from the Twin Creek mine are three times higher than estimated emissions from North Block; therefore, Twin Creek has greater influence in this subregion. Map R4-24 depicts simulated SP concentrations in the proximity of North Block and Twin Creek. Predicted concentrations in this subregion are higher than anywhere else in the ES region. The maximum predicted concentration of 322 $\mu g/m^3$ is predicted to occur less than 2 miles south of Twin Creek and North Block, resulting in high impact from northerly wind flow. Elsewhere within the subregion, predicted levels range from 20 to 120 $\mu g/m^3$.

Predicted SP levels in the immediate vicinity of the South Haystack mine are shown in Map R4-25. Peak simulated levels of approximately 80 $\mu g/m^3$ occur in a small region south of the South Haystack mine.

(Note that emissions from the mine are projected to decrease in 1985.) Such levels, for the most part, are attributable to emissions emanating from South Haystack influenced by a north wind. The contribution from the North Block and Twin Creek mines is minimal so close to South Haystack. However, the interaction phenomenon induced by north wind flow is evident further downwind. Elsewhere, the South Haystack mine is the sole source of predicted levels within about 40 miles east or west of the mine site.

For PSD increments, simulated concentrations in the Bridger Wilderness Area are less than 2 $\mu g/m^3$, which does not interfere with the 10 $\mu g/m^3$ Class I increment. The remaining portion of southwest Wyoming is designated Class II; except for Long Canyon simulated concentrations above the 37 $\mu g/m^3$ allowable PSD increment are predicted to occur as far out as 12 miles from some of the mine sites.

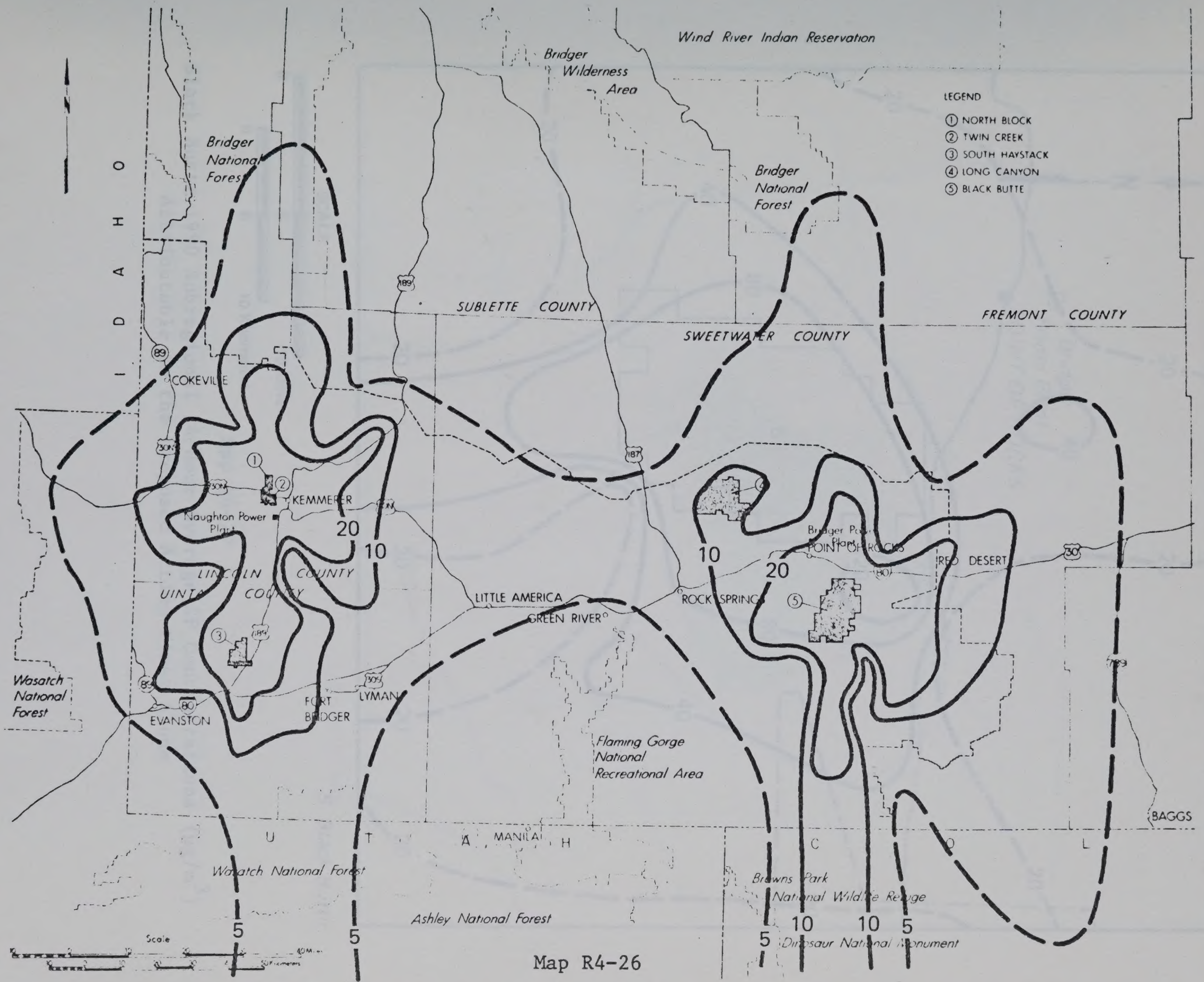
At the present time, both the Flaming Gorge National Recreation Area and Fossil Butte National Monument are Class II regions, but have the potential to be redesignated to Class I. Predicted worst-case 24-hour average concentrations at Flaming Gorge are approximately 5 $\mu g/m^3$ or less than the 10 $\mu g/m^3$ Class I increment. However, at the Fossil Butte National Monument, simulated SP levels are about 20 $\mu g/m^3$, which exceeds the Class I increment but does not exceed the allowable Class II increment of 37 $\mu g/m^3$.

The area located 6 miles north of Green River is designated a NA area. Simulated SP impact for this region is approximately 7 $\mu g/m^3$, which is approximately 3% of the federal 260 $\mu g/m^3$ standard.

Model Predictions of 24-Hour Average Impact on SP Concentrations for 1990

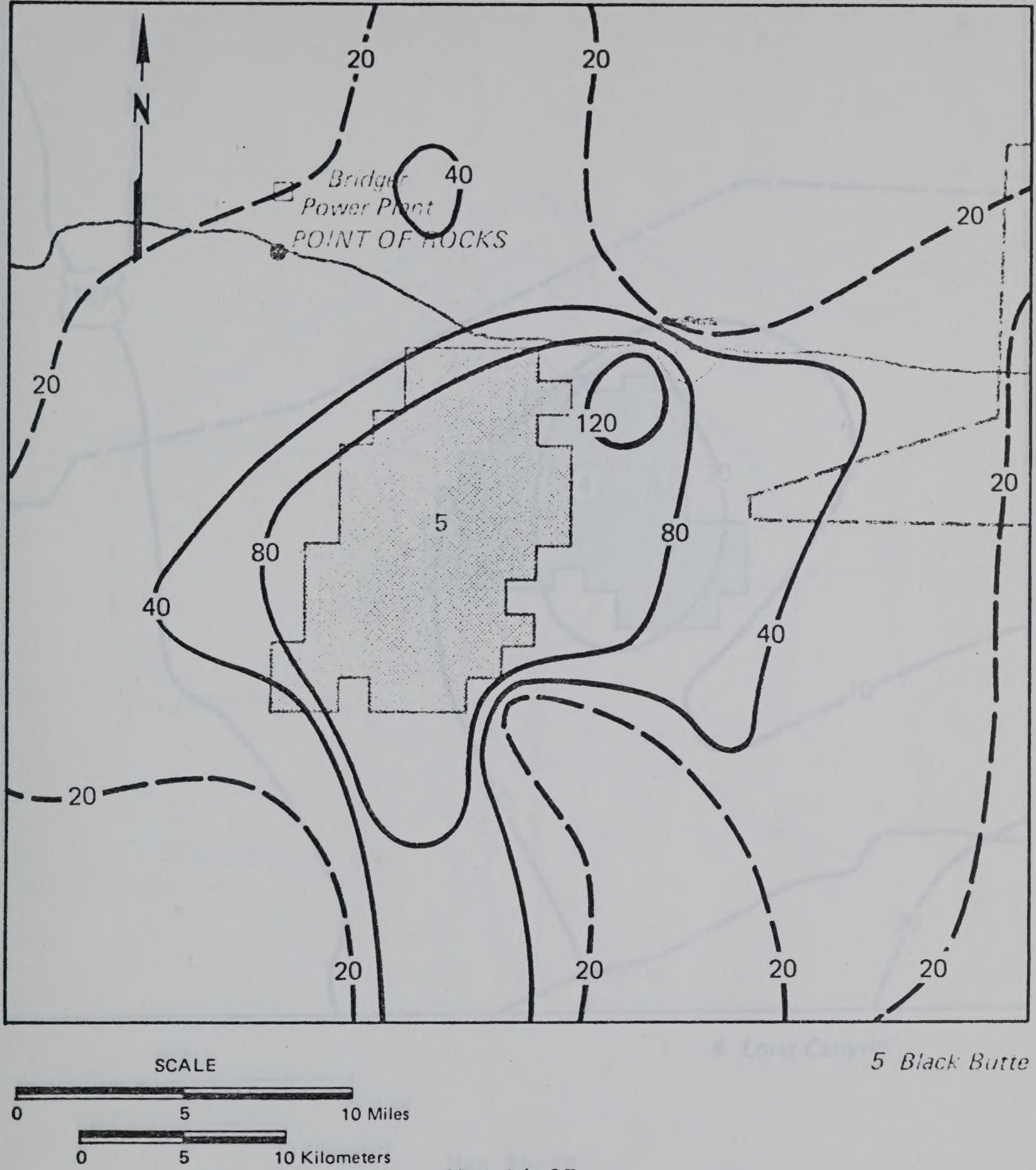
The predicted impacts from the proposed action mines in 1990 are presented in Maps R4-26 through R4-30. Regionally, simulated SP concentrations range from 5 to approximately 120 $\mu g/m^3$; the highest impacts are predicted to occur in the near vicinity of the mine sites. In the Rock Springs area, worst-case predicted SP levels are generally determined from fugitive dust emissions at Black Butte. Similar to 1980 and 1985, emissions from Black Butte are vastly higher than emissions from the Long Canyon mine. Consequently, dispersion of emissions from the Black Butte mine determines predicted impact as a result of the wind direction lining up Black Butte with such receptors. The only significant influence resulting from Long Canyon emissions is to receptors located very close (within 3 to 5 miles) to the Long Canyon mine. Predicted SP levels close to the Black Butte and Long Canyon mines are depicted in Maps R4-27 and R4-28. Peak concentrations of approximately 20 $\mu g/m^3$ are predicted to occur about the Long Canyon mine. These concentrations result from a northerly wind flow dispersing emissions from Long Canyon.

803281
803287


Wind River Indian Reservation
Bridger Wilderness Area
Bridger National Forest
Bridger National Forest
LEGEND
① NORTH BLOCK
② TWIN CREEK
③ SOUTH HAYSTACK
④ LONG CANYON
⑤ BLACK BUTTE
I D A H O
SUBLETTE COUNTY
SWEETWATER COUNTY
FREMONT COUNTY
LINCOLN COUNTY
UINTA COUNTY
COKEVILLE
KEMMERER
Naughton Power Plant
Bridger Power Plant
POINT OF ROCKS
RED DESERT
LITTLE AMERICA
GREEN RIVER
ROCK SPRINGS
EVANSTON
FORT BRIDGER
LYMAN
Wasatch National Forest
Flaming Gorge National Recreational Area
BAGGS
U T A H
MANILA
C O L
Wasatch National Forest
Ashley National Forest
Browns Park National Wildlife Refuge
Dinosaur National Monument
20
10
10
20
5
5
5
10
10
5
Scale
40 Miles
50 Kilometers
89
30N
189
187
80
30
789
84

Map R4-26

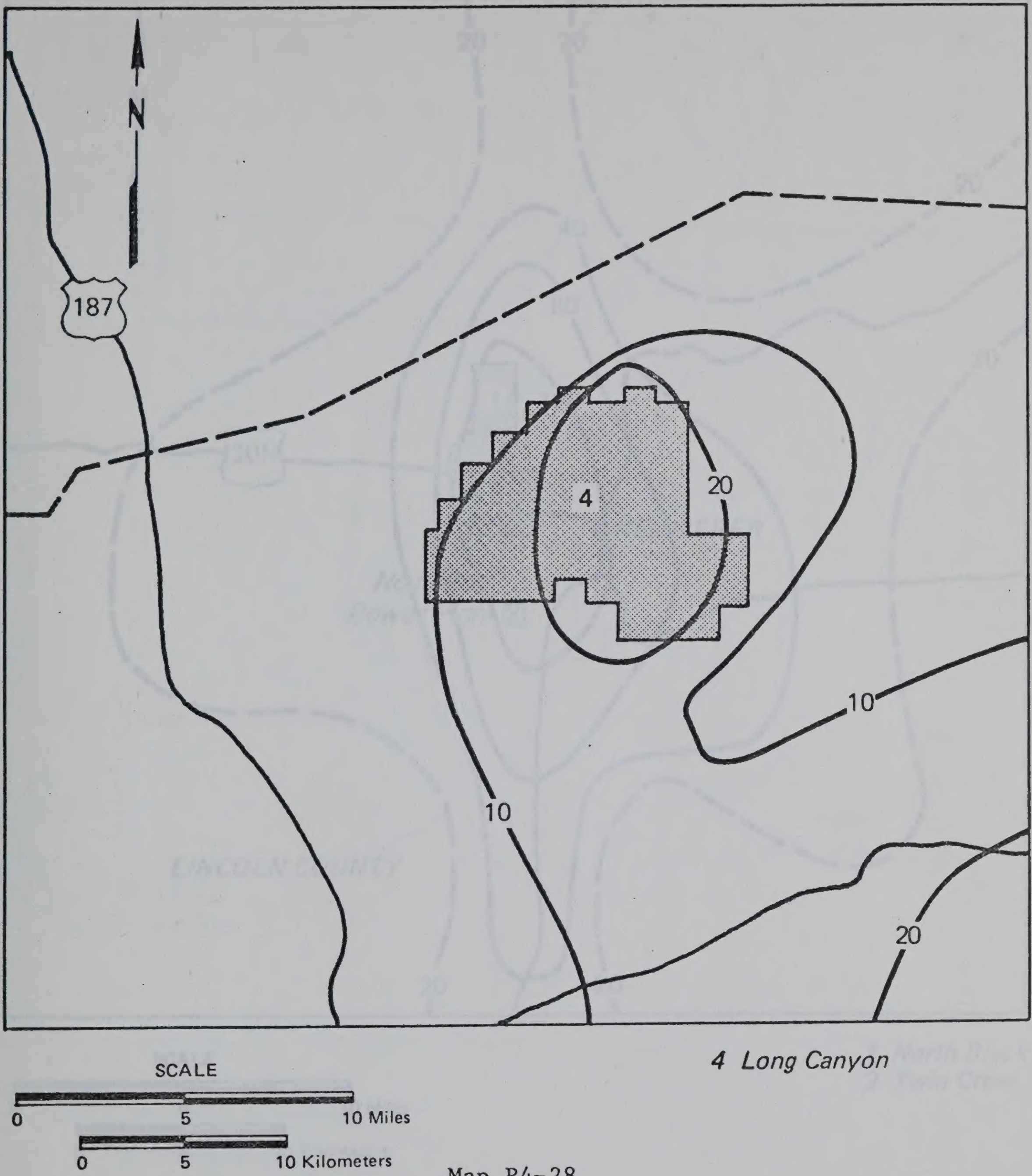
1990 Predicted 24-Hour Average SP Concentrations (μg/m^3)
Attributable to the Proposed Action Mines Alone


N
20
20
Bridger Power Plant
40
POINT OF ROCKS
20
20
120
20
5
80
80
40
40
20
20
20
20
20
SCALE
0
5
10 Miles
0
5
10 Kilometers
5 Black Butte

Map R4-27

Black Butte 1990 Subregional 24-Hour Average SP Concentrations ($\mu g/m^3$) Attributable to the Proposed Action Mines Alone

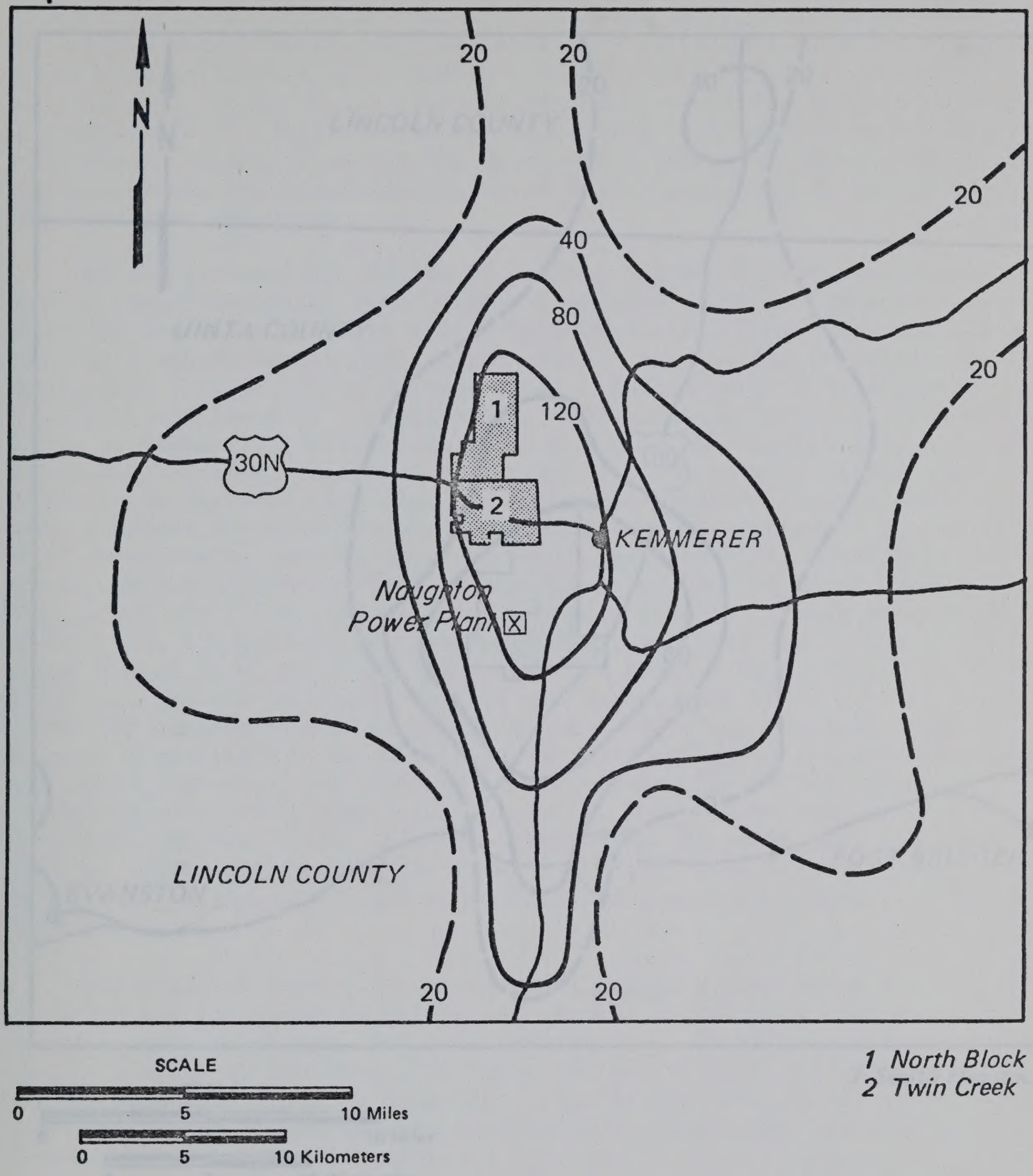
801143
803235


N
187
4
20
10
10
20
4 Long Canyon
SCALE
0
5
10 Miles
0
5
10 Kilometers

Map R4-28

Long Canyon 1990 Subregional 24-Hour Average SP Concentrations ($\mu g/m^3$) Attributable to the Proposed Action Mines Alone

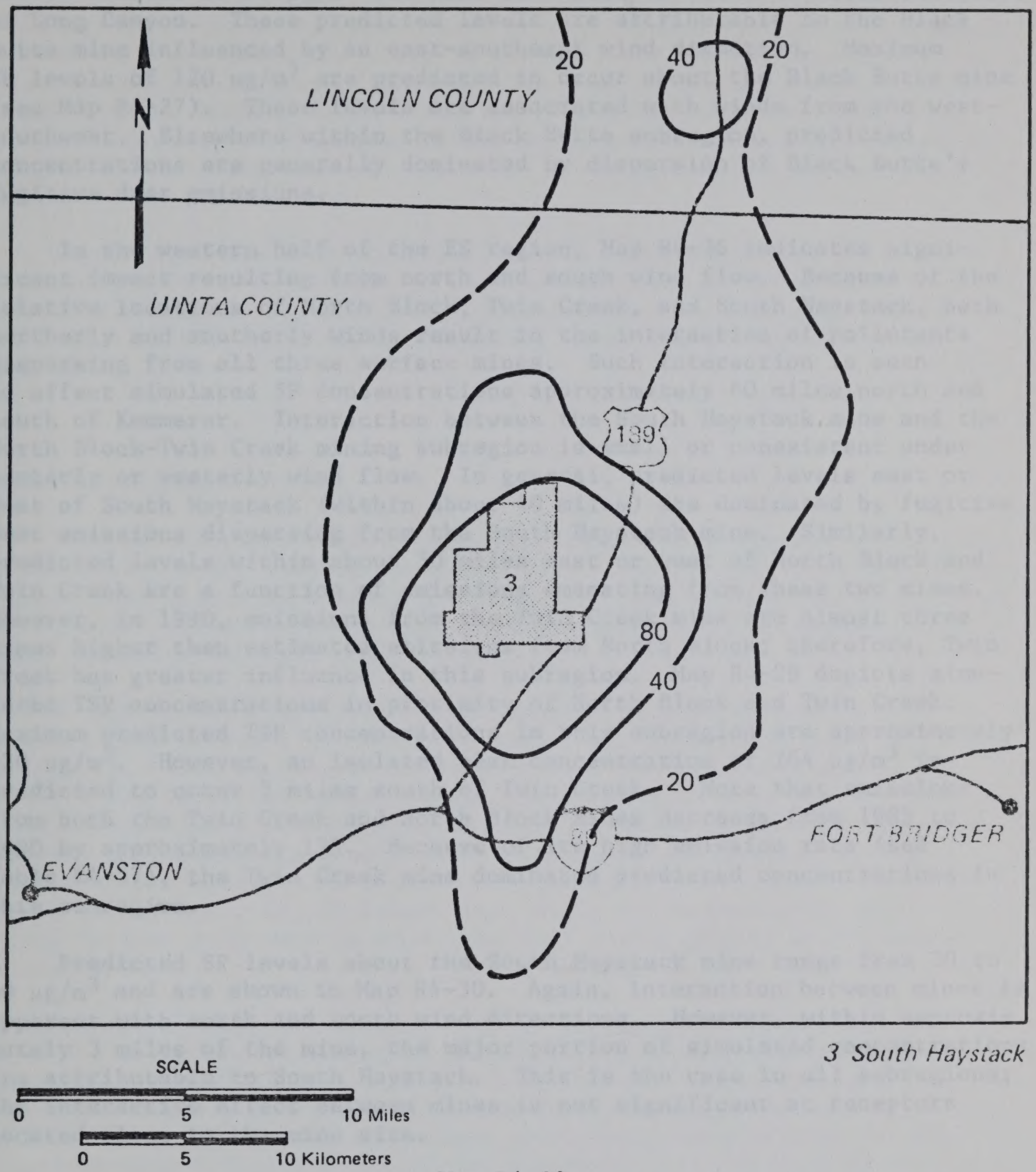
801141
803337


N
20
20
20
40
80
20
120
1
2
30N
KEMMERER
Naughton Power Plant
LINCOLN COUNTY
20
20
SCALE
0
5
10 Miles
0
5
10 Kilometers
1 North Block
2 Twin Creek

X = Maximum Predicted Concentration = 264 μg/m^3

Map R4-29

North Block - Twin Creek 1990 Subregional 24-Hour Average SP Concentrations (μg/m^3) Attributable to the Proposed Action Mines Alone


20
40
20
LINCOLN COUNTY
N
UINTA COUNTY
189
3
80
40
20
80
EVANSTON
FORT BRIDGER
3 South Haystack
SCALE
0
5
10 Miles
0
5
10 Kilometers

Map R4-30

South Haystack 1990 Subregional 24-Hour Average SP Concentrations ($\mu g/m^3$) Attributable to the Proposed Action Mines Alone

Concentrations of 20 μg/m^3 are also simulated to occur 12 miles southeast of Long Canyon. These predicted levels are attributable to the Black Butte mine influenced by an east-southeast wind direction. Maximum SP levels of 120 μg/m^3 are predicted to occur about the Black Butte mine (see Map R4-27). These levels are associated with winds from the west-southwest. Elsewhere within the Black Butte subregion, predicted concentrations are generally dominated by dispersion of Black Butte's fugitive dust emissions.

In the western half of the ES region, Map R4-26 indicates significant impact resulting from north and south wind flow. Because of the relative locations of North Block, Twin Creek, and South Haystack, both northerly and southerly winds result in the interaction of pollutants dispersing from all three surface mines. Such interaction is seen to affect simulated SP concentrations approximately 60 miles north and south of Kemmerer. Interaction between the South Haystack mine and the North Block-Twin Creek mining subregion is small or nonexistent under easterly or westerly wind flow. In general, predicted levels east or west of South Haystack (within about 40 miles) are dominated by fugitive dust emissions dispersing from the South Haystack mine. Similarly, predicted levels within about 50 miles east or west of North Block and Twin Creek are a function of emissions emanating from these two mines. However, in 1990, emissions from the Twin Creek mine are almost three times higher than estimated emissions from North Block; therefore, Twin Creek has greater influence in this subregion. Map R4-29 depicts simulated TSP concentrations in proximity of North Block and Twin Creek. Maximum predicted TSP concentrations in this subregion are approximately 120 μg/m^3. However, an isolated peak concentration of 264 μg/m^3 is predicted to occur 3 miles south of Twin Creek. Note that emissions from both the Twin Creek and North Block mines decrease from 1985 to 1990 by approximately 17%. Because of its high emission rate (see Table R4-57), the Twin Creek mine dominates predicted concentrations in this subregion.

Predicted SP levels about the South Haystack mine range from 20 to 80 μg/m^3 and are shown in Map R4-30. Again, interaction between mines is apparent with north and south wind directions. However, within approximately 3 miles of the mine, the major portion of simulated concentrations are attributable to South Haystack. This is the case in all subregions; the interactive effect between mines is not significant at receptors located close to the mine site.

Concentrations of SP predicted to occur throughout the Class I Bridger Wilderness Area are about 1 μg/m^3, well below the 10 μg/m^3 allowable PSD increment. The allowable PSD increment for the rest of southwest Wyoming (designated Class II) is maintained regionally except in the vicinity of the surface mines. Except for Long Canyon, predicted TSP levels within 6 to 12 miles of the mine sites exceed the 37 μg/m^3 increment (see Maps R4-27, R4-29 and R4-30).

The Flaming Gorge Recreational Area shown on Map R4-26 and the Fossil Butte National Monument (located approximately 10 miles northwest of Kemmerer) are currently Class II regions, but may be redesignated to Class I. Concentrations of SP less than 5 $\mu g/m^3$ are predicted to occur throughout the Flaming Gorge Area, which complies with the Class I 10 $\mu g/m^3$ increment. Predicted levels at Fossil Butte are approximately 20 $\mu g/m^3$, which complies with the Class II increment but exceeds the allowable Class I increment.

Impact from the most probable level of mining development in 1990 is indicated for the NA trona patch, 6 miles north of Green River. As indicated in Map R4-26, predicted concentrations in this area are on the order of 5 $\mu g/m^3$, which is approximately 2% of the 260 $\mu g/m^3$ federal standard.

Gaseous Pollutants

Vehicle emissions would be the only source of gaseous air pollutants attributable to the proposed action mines. Federal and state regulations include limitations on ambient air concentrations of the vehicle-related pollutants: carbon monoxide (CO), hydrocarbons (HC), nitrogen dioxide (NO_2) and sulfur dioxide (SO_2).

Ambient concentrations were not modeled because of the lack of detailed data on vehicle use and of applicable background data for these pollutants. However, recent studies (U.S. Department of the Interior 1976) of the impact of vehicle emissions associated with western coal mines were reviewed to estimate the probable range of impact. In these studies, concentrations of the above pollutants for similar mining operations had either been modeled or estimated from standard approximation techniques. In all cases, the levels of maximum pollutant concentrations from vehicle emissions were insignificant when compared to standards.

Maximum predicted concentrations of CO ranged between 0.02 and 0.44% of the 1-hour 40,000 $\mu g/m^3$ standard. Maximum predicted HC concentrations ranged between 0.88 and 3.44% of the 3-hour 160 $\mu g/m^3$ standard. Maximum predicted NO_2 concentrations ranged between 0.60 and 3.0% of the standards, while maximum predicted concentrations of SO_2 ranged between 0.02 and 0.33% of the standards. Air quality standards for SO_2 and NO_x are shown in Table R4-64. The values represent predictions at less than one-half mile from the mines. Predictions were significantly less at distances further from the mines. Assuming similar vehicle activity for all western coal mines, the regional cumulative impact of vehicle emissions on ambient concentrations of gaseous pollutants would be minimal and insignificant compared to their respective standards.

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Sec. BG
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The Flaming Gorge Recreational Area shown on Map RA-75 and the Fossil Butte National Monument (located approximately 10 miles northwest of Kemmerer) are currently Class II regions, but may be redesignated to Class I. Concentrations of SP less than 3 ug/m³ are predicted to occur throughout the Flaming Gorge Area, which complies with the Class I 10 ug/m³ increment. Predicted levels at Fossil Butte are approximately 20 ug/m³, which complies with the Class II increment but exceeds the allowable Class I increment.

Impact from the most probable level of mining development in 1990 is indicated for the SO group patch, 6 miles north of Green River. As indicated in Map RA-76, predicted concentrations in this area are on the order of 5 ug/m³, which is approximately 2% of the 260 ug/m³ federal standard.

Gaseous Pollutants

Vehicle emissions would be the only source of gaseous air pollutants attributable to the proposed action mines. Federal and state regulations include limitations on ambient air concentrations of the vehicle-related pollutants: carbon monoxide (CO), hydrocarbons (HC), nitrogen dioxide (NO_2) and sulfur dioxide (SO_2).

Ambient concentrations were not modeled because of the lack of detailed data on vehicle use and of applicable background data for these pollutants. However, recent studies (U.S. Department of the Interior 1976) of the impact of vehicle emissions associated with western coal mines were reviewed to estimate the probable range of impact. In these studies, concentrations of the above pollutants for similar mining operations had either been modeled or estimated from standard approximation techniques. In all cases, the levels of maximum pollutant concentrations from vehicle emissions were insignificant when compared to standards.

Maximum predicted concentrations of CO ranged between 0.02 and 0.44% of the 1-hour 40,000 ug/m³ standard. Maximum predicted HC concentrations ranged between 0.88 and 3.44% of the 3-hour 160 ug/m³ standard. Maximum predicted NO_2 concentrations ranged between 0.60 and 3.0% of the standards, while maximum predicted concentrations of SO_2 ranged between 0.02 and 0.13% of the standards. Air quality standards for SO_2 and CO are shown in Table RA-64. The values represent predictions at less than one-half mile from the mines. Predictions were significantly less at distances further from the mines. Assuming similar vehicle activity for all western coal mines, the regional cumulative impact of vehicle emissions on ambient concentrations of gaseous pollutants would be minimal and insignificant compared to their respective standards.

TABLE R4-64

STATE OF WYOMING AND NATIONAL AMBIENT AIR QUALITY STANDARDS FOR CONCENTRATIONS OF TSP, SO_2, AND NO_2

Pollutant	Averaging Time	Standard ($\mu g/m^3$)		
		Federal		Wyoming
		Primary*	Secondary**	
TSP	Annual†	75	60§	60
	24-Hour††	260	150	150
SO_2	Annual§§	80		60
	24-Hour††	365		260
	3-Hour††		1,300	1,300
NO_2	Annual§§	100	100	100

*Requisite to protect human health.

**Requisite to protect the public welfare from any known or anticipated adverse effects.

†Geometric Mean

††Not to be exceeded more than once per year.

§Guideline

§§Arithmetic Mean

Cumulative Impacts on Air Quality

Cumulative impacts refers to total suspended particulate (TSP) concentrations attributable to the proposed action mines, plus the private projected mines (Winton and Reliance), plus projected background. Winton and Reliance were modeled similarly to the proposed action mines, and predicted impacts were determined. Background is defined as the conglomeration of SP levels attributable to all sources throughout the ES region other than the proposed mines that were modeled. The resultant total concentrations characterize predicted ambient air quality; and, hence, these totals may be directly compared to both the federal and Wyoming ambient air quality standards shown in Table R4-64. The simulated annual and 24-hour average SP levels attributable to the proposed actions alone were discussed in previous sections. The background SP concentrations to be added to the proposed action and Winton and Reliance mine simulations for each analysis year are presented in Table R4-65. These levels are categorized as representative of rural, industrial, or urban background within each county in the ES region.

In general, the industrial category corresponds to the area along interstate 80 between Little America and Rock Springs, where several point sources are located (this area is referred to as the "trona patch"), and the areas in the vicinity of the Naughton and Bridger Power Plants. The urban category characterizes background about the urban areas within the ES region, such as Rock Springs, Kemmerer, Evanston, and Green River. Rural background corresponds to the remainder of southwest Wyoming. Background levels presented in Table R4-65 exhibit a wide range within each category, indicative of a large degree of uncertainty associated with regional background levels. As discussed in Chapter 2, these background concentrations are derived from a small number of monitors within the region and the background ranges presented in Table R4-65 are merely approximations of trends in regional SP air quality. It should be noted, however, that the geographical representativeness of a particulate monitor is limited, and background levels at locations relatively distant from the monitors could be quite different.

For short-term averages, it is unlikely that the meteorology corresponding to the measured background concentrations is coincident with the 24-hour period determining worst-case impacts attributable to the proposed actions. Without coincident meteorology, the predicted cumulative impacts could not possibly occur. However, in an attempt to quantify cumulative TSP impacts, such worst-case assumptions have been made. Pictorial representations of cumulative regional TSP impacts on annual and 24-hour average concentrations are shown in Maps R4-30 through R4-36 for all three analysis years. The depicted isopleths represent simulated SP levels attributable to the proposed action and the Winton and Reliance mines in combination with the midpoints of the background ranges given in Table R4-65. Use of these background range midpoints is purely arbitrary and done for illustrative purposes only;

TABLE R4-65

BACKGROUND TSP CONCENTRATIONS
($\mu g/m^3$)

Period of Interest	TSP Averaging Period	Sweetwater County			Lincoln/Uinta Counties		
		Rural TSP	Industrial TSP	Urban TSP	Rural TSP	Industrial TSP	Urban TSP
Baseline	Annual	10-20	20-35	35-45	10-20	20-35	20-35
	24-Hr	35-50	45-160	80-155	30-45	60-85	60-85
1980	Annual	13-23	23-45	33-43	10-20	18-28	18-28
	24-Hr	30-55	60-225	70-130	30-50	50-75	50-75
1985	Annual	13-23	23-45	28-38	10-20	18-28	18-28
	24-Hr	30-55	60-225	55-110	30-50	50-75	50-75
1990	Annual	13-23	23-45	23-35	10-20	18-28	18-28
	24-Hr	30-55	60-225	50-100	30-50	50-75	50-75

TABLE R4-65

BACKGROUND TSP CONCENTRATIONS
($\mu g/m^3$)

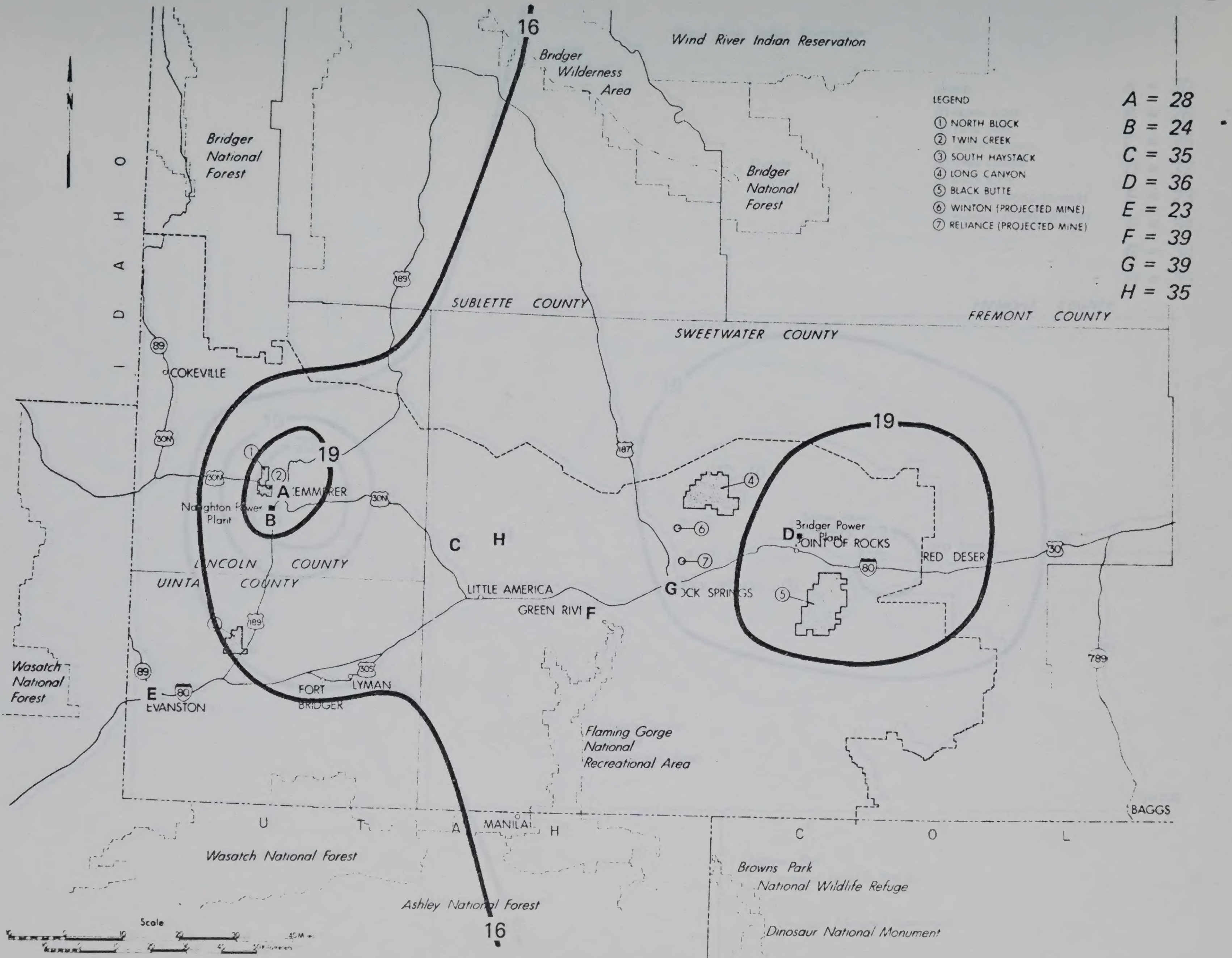
Period of Interest	TSP Averaging Period	Sweetwater County			Lincoln/Uinta Counties		
		Rural TSP	Industrial TSP	Urban TSP	Rural TSP	Industrial TSP	Urban TSP
Baseline	Annual	10-20	20-35	35-45	10-20	20-35	20-35
	24-Hr	35-50	45-160	80-155	30-45	60-85	60-85
1980	Annual	13-23	23-45	33-43	10-20	18-28	18-28
	24-Hr	30-55	60-225	70-130	30-50	50-75	50-75
1985	Annual	13-23	23-45	28-38	10-20	18-28	18-28
	24-Hr	30-55	60-225	55-110	30-50	50-75	50-75
1990	Annual	13-23	23-45	23-35	10-20	18-28	18-28
	24-Hr	30-55	60-225	50-100	30-50	50-75	50-75

the likelihood of its actual occurrence is unknown. The reader can just as easily choose any point within the given ranges to determine cumulative impacts. Maps R4-30 through R4-36 are characterized by a gross smoothing effect in comparison with the maps depicting impact from the proposed actions alone. The domination of background accounts for such TSP distributions. Note that letters A through H on the cumulative maps depict isolated receptor points of maximum predicted TSP concentrations.

The basis for determining cumulative impacts must be stressed prior to evaluation. Namely, ambient particulate levels measured at a limited number of available monitors are assumed to characterize background concentrations throughout the entire ES region and meteorology is assumed to be coincident for background levels and simulated SP impacts attributable to the proposed actions. Cumulative TSP impact discussions that follow delineate a range of predicted concentrations in accordance with Table R4-65 since at any distance from an existing monitoring site, the true deviation of regional background levels is unknown.

Predicted Annual Average Cumulative Impacts on SP Concentrations for 1980, 1985, and 1990. In 1980, the highest background concentrations are projected for the industrial and urban sectors of Sweetwater County. When combined with simulated mine concentrations, resultant total levels about both the trona patch and Bridger Power Plant range from 24 to 46 $\mu g/m^3$. (Note that Winton and Reliance are not operational in 1980.) Ranges of TSP of 34 to 44 are predicted to occur in the vicinity of Rock Springs. To these cumulative totals, mining activities contribute less than 4%. In the proximity of Kemmerer, projected background plus mine simulations result in total TSP concentrations of 23 to 33 $\mu g/m^3$; background alone accounts for approximately 80% of these levels. The remainder is attributable primarily to the Twin Creek mine. Close to the Black Butte mine, where simulated mine concentrations are the highest in the region for 1980, cumulative concentrations range from 20 to 30 $\mu g/m^3$ Black Butte accounts for less than 40% of these levels; the remainder is attributable to background. Near the South Haystack mine, cumulative levels range from 15 to 25 $\mu g/m^3$. The South Haystack mine alone accounts for one-third of these concentrations; the rest is attributable to background. Regionally, background sources account for the majority of cumulative TSP levels. In the vicinity of the mine sites, the contribution from the mines to total predicted levels is greater than elsewhere, however, background levels still dominate.

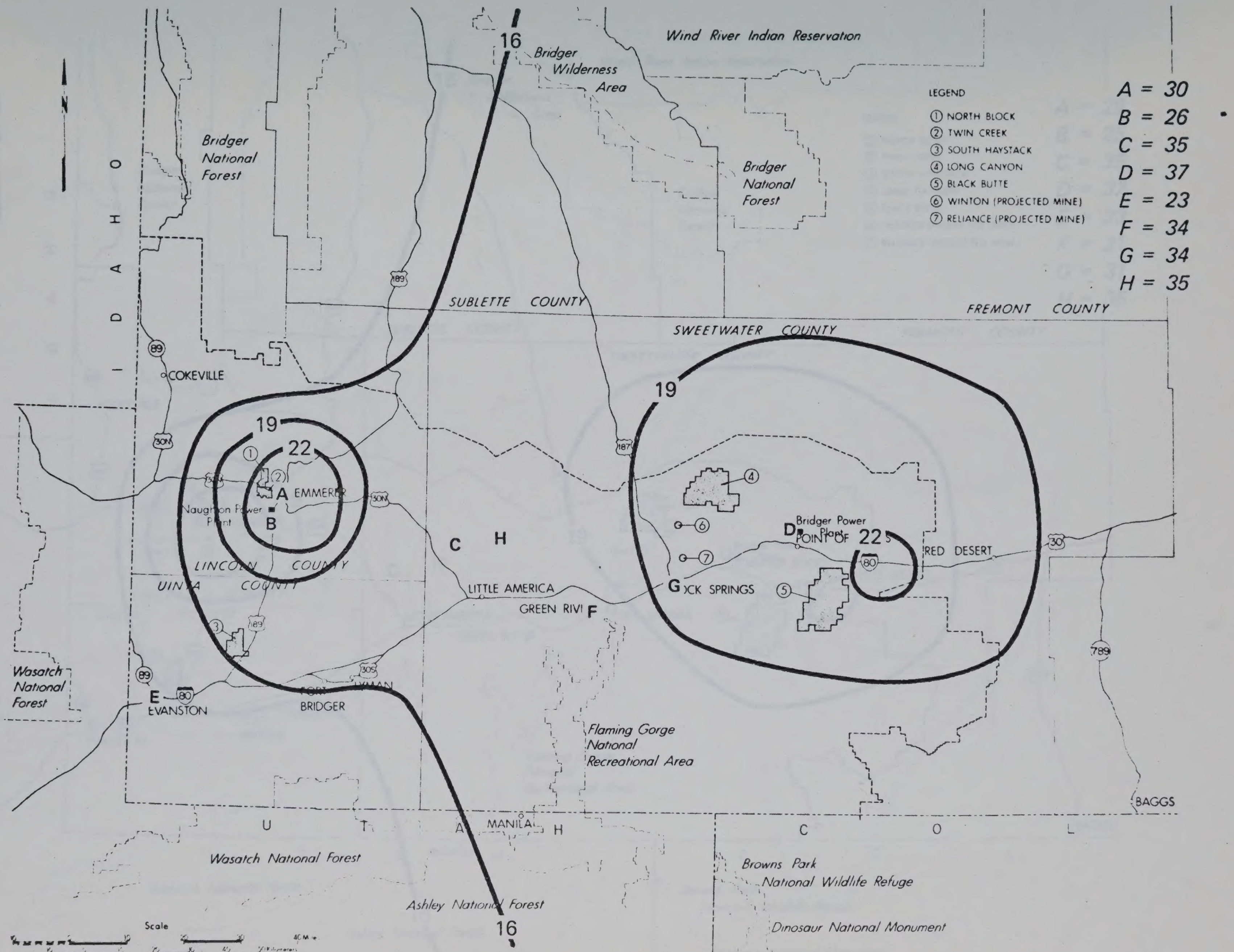
Similar to 1980, the highest background concentrations are projected to occur in the industrial and urban sectors of Sweetwater County for 1985 and 1990. Cumulative concentrations for both years range from 24 to 46 $\mu g/m^3$ about the trona patch and 25 to 47 $\mu g/m^3$ in the vicinity of the Jim Bridger Power Plant. Background alone accounts for greater than 92% of such levels. In the Rock Springs area, total predicted ambient air quality levels range from 24 to 39 $\mu g/m^3$ in 1985 and 26 $\mu g/m^3$ to 36 $\mu g/m^3$ in 1990. Again, background alone contributes


16
Bridger Wilderness Area
Wind River Indian Reservation
LEGEND
① NORTH BLOCK
② TWIN CREEK
③ SOUTH HAYSTACK
④ LONG CANYON
⑤ BLACK BUTTE
⑥ WINTON (PROJECTED MINE)
⑦ RELIANCE (PROJECTED MINE)
A = 28
B = 24
C = 35
D = 36
E = 23
F = 39
G = 39
H = 35
Bridger National Forest
Bridger National Forest
IDAHO
N
189
SUBLETTE COUNTY
FREMONT COUNTY
SWEETWATER COUNTY
89
COKEVILLE
30N
19
A
KEMMERER
Naughton Power Plant
B
187
19
④
⑥
⑦
Bridger Power Plant
D
POINT OF ROCKS
RED DESERT
30
80
C
H
LINCOLN COUNTY
UINTA COUNTY
LITTLE AMERICA
GREEN RIVER
F
G
ROCK SPRINGS
⑤
189
89
Wasatch National Forest
E
80
EVANSTON
FORT BRIDGER
30S
LYMAN
789
Flaming Gorge National Recreational Area
BAGGS
UTAH
MANILA
COL
Wasatch National Forest
Browns Park National Wildlife Refuge
Ashley National Forest
Dinosaur National Monument
16
Scale

Map R4-31

Cumulative 1980 Predicted Annual Average TSP Concentrations ($\mu g/m^3$)

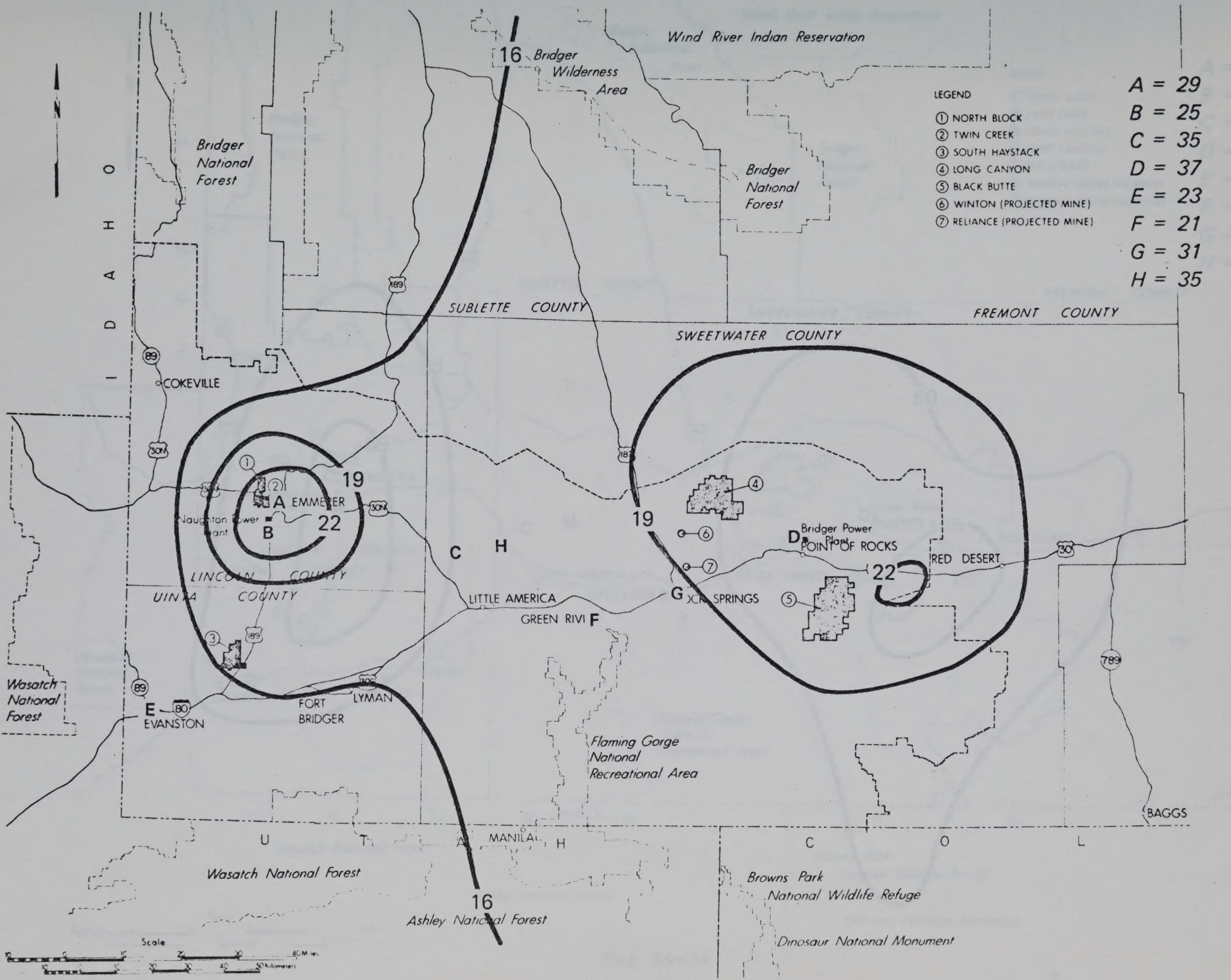
803288
803342



16
Bridger Wilderness Area
Wind River Indian Reservation
Bridger National Forest
Bridger National Forest
LEGEND
① NORTH BLOCK
② TWIN CREEK
③ SOUTH HAYSTACK
④ LONG CANYON
⑤ BLACK BUTTE
⑥ WINTON (PROJECTED MINE)
⑦ RELIANCE (PROJECTED MINE)
A = 30
B = 26
C = 35
D = 37
E = 23
F = 34
G = 34
H = 35
N
I D A H O
SUBLETTE COUNTY
FREMONT COUNTY
SWEETWATER COUNTY
COKEVILLE
19
19
22
22
A EMMERER
Naughton Power Plant
B
C H
LINCOLN COUNTY
UINTA COUNTY
LITTLE AMERICA
GREEN RIVI F
G ƆCK SPRINGS
D Bridger Power Plant
POINT OF
RED DESERT
Wasatch National Forest
E EVANSTON
FORT BRIDGER
LYMAN
Flaming Gorge National Recreational Area
BAGGS
U T A H
MANILA
C O L
Wasatch National Forest
Ashley National Forest
Browns Park National Wildlife Refuge
Dinosaur National Monument
Scale
16
89
30N
189
187
80
30
789

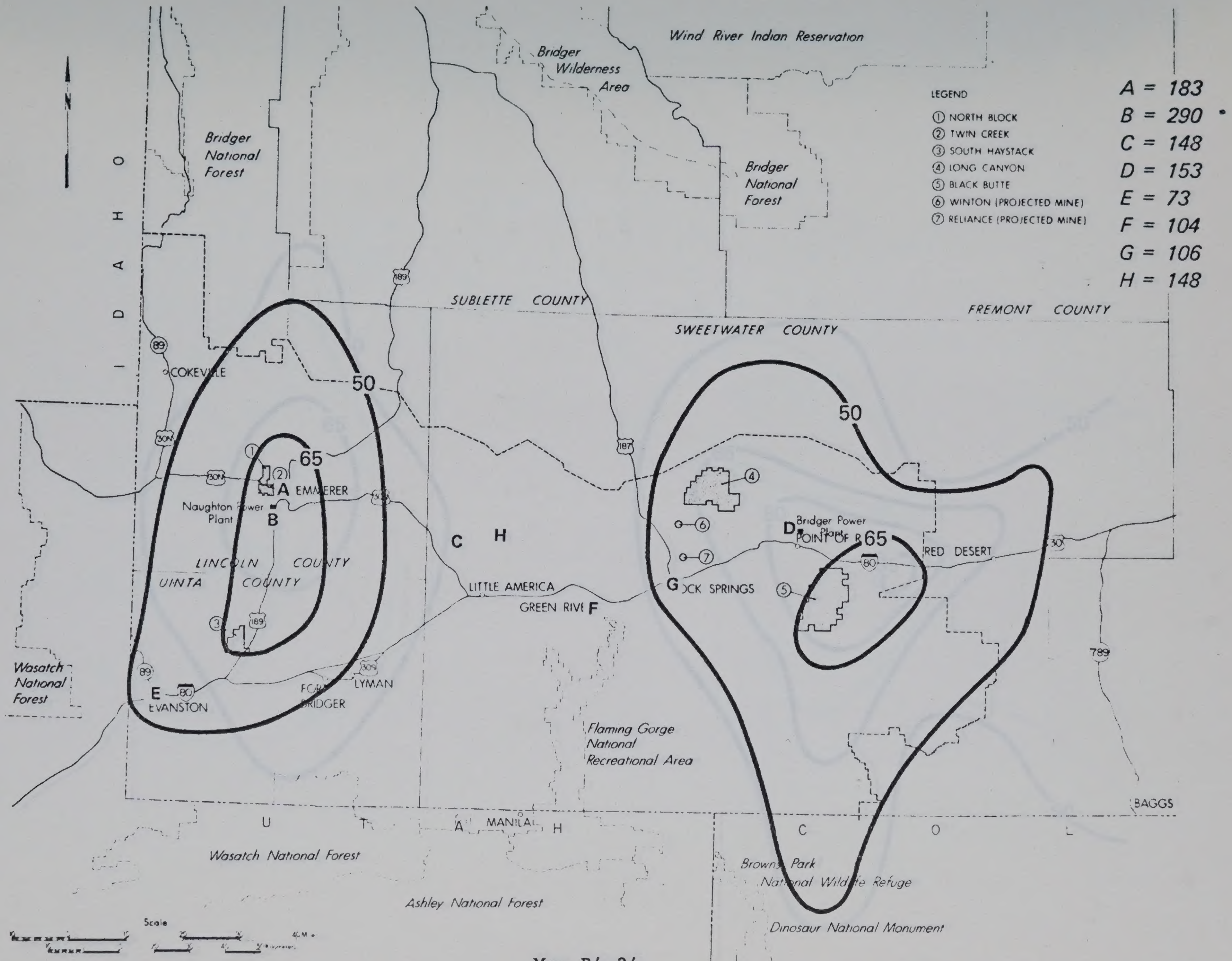
Map R4-32

Cumulative 1985 Predicted Annual Average TSP Concentrations (μg/m^3)


N
I D A H O
16
Bridger Wilderness Area
Wind River Indian Reservation
LEGEND
① NORTH BLOCK
② TWIN CREEK
③ SOUTH HAYSTACK
④ LONG CANYON
⑤ BLACK BUTTE
⑥ WINTON (PROJECTED MINE)
⑦ RELIANCE (PROJECTED MINE)
A = 29
B = 25
C = 35
D = 37
E = 23
F = 21
G = 31
H = 35
Bridger National Forest
Bridger National Forest
189
SUBLETTE COUNTY
FREMONT COUNTY
SWEETWATER COUNTY
89
COKEVILLE
30N
19
A EMMERER
Naughton Power Plant
B
22
30N
187
19
Bridger Power Plant
D
POINT OF ROCKS
22
RED DESERT
30
C
H
LINCOLN COUNTY
UINTA COUNTY
LITTLE AMERICA
GREEN RIVI F
G
ROCK SPRINGS
189
89
789
Wasatch National Forest
E
80
EVANSTON
FORT BRIDGER
LYMAN
30S
Flaming Gorge National Recreational Area
BAGGS
U T A H
C O L
MANILA
Wasatch National Forest
Browns Park National Wildlife Refuge
Dinosaur National Monument
16
Ashley National Forest
Scale
40 Miles
50 Kilometers

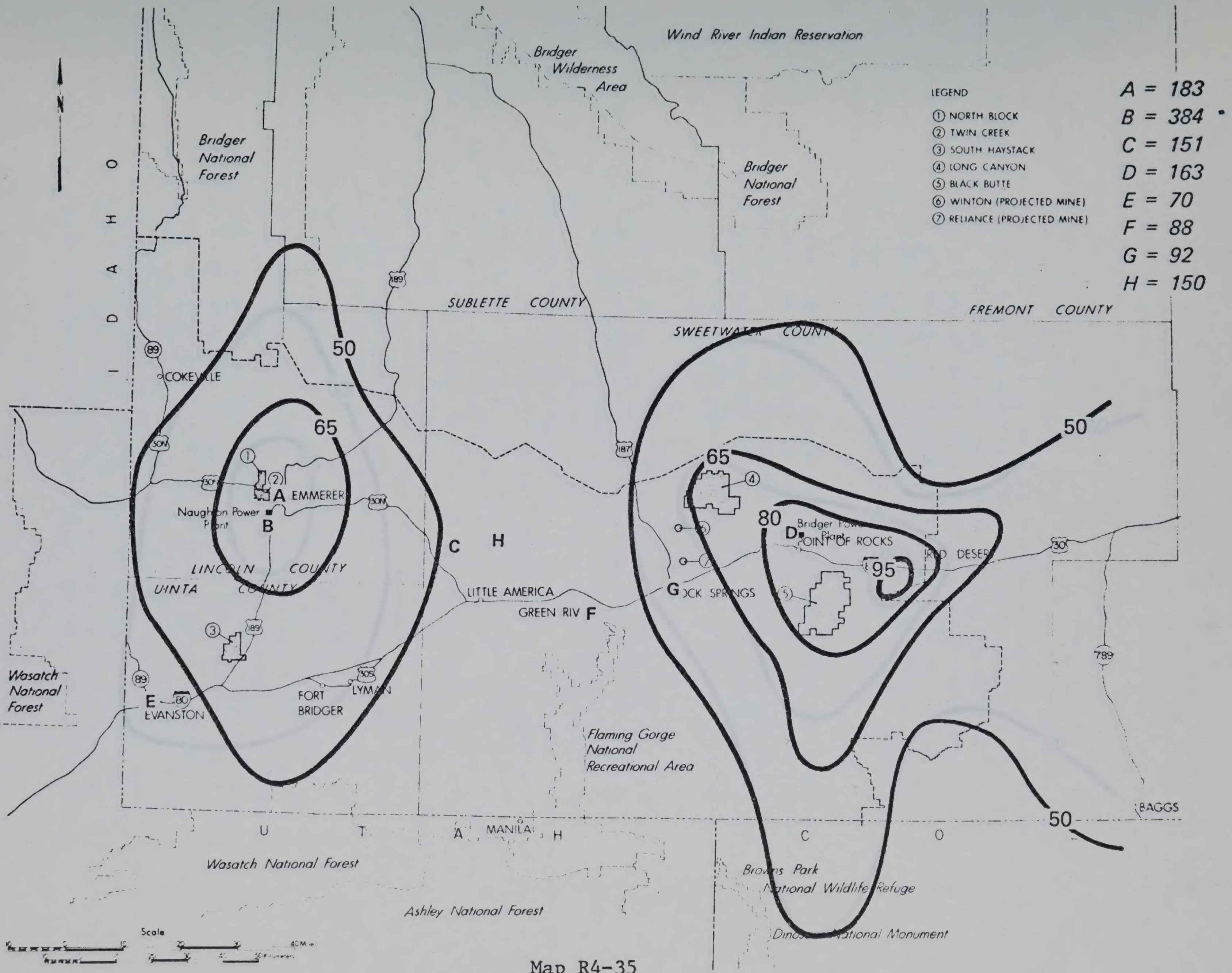
Map R4-33

Cumulative 1990 Predicted Annual Average TSP Concentrations ($\mu g/m^3$)


Wind River Indian Reservation
Bridger Wilderness Area
Bridger National Forest
Bridger National Forest
IDAHO
LEGEND
① NORTH BLOCK
② TWIN CREEK
③ SOUTH HAYSTACK
④ LONG CANYON
⑤ BLACK BUTTE
⑥ WINTON (PROJECTED MINE)
⑦ RELIANCE (PROJECTED MINE)
A = 183
B = 290
C = 148
D = 153
E = 73
F = 104
G = 106
H = 148
SUBLETTE COUNTY
FREMONT COUNTY
SWEETWATER COUNTY
COKEVILLE
50
65
50
65
A EMMERER
Naughton Power Plant
B
C
H
D
Bridger Power Plant
POINT OF R
RED DESERT
LINCOLN COUNTY
UINTA COUNTY
LITTLE AMERICA
GREEN RIVER F
G OCK SPRINGS
E EVANSTON
FORT BRIDGER
LYMAN
Wasatch National Forest
Flaming Gorge National Recreational Area
UTAH
MANILA
COLO
BAGGS
Wasatch National Forest
Ashley National Forest
Browns Park National Wildlife Refuge
Dinosaur National Monument
Scale
89
30N
189
187
80
30
789

Map R4-34

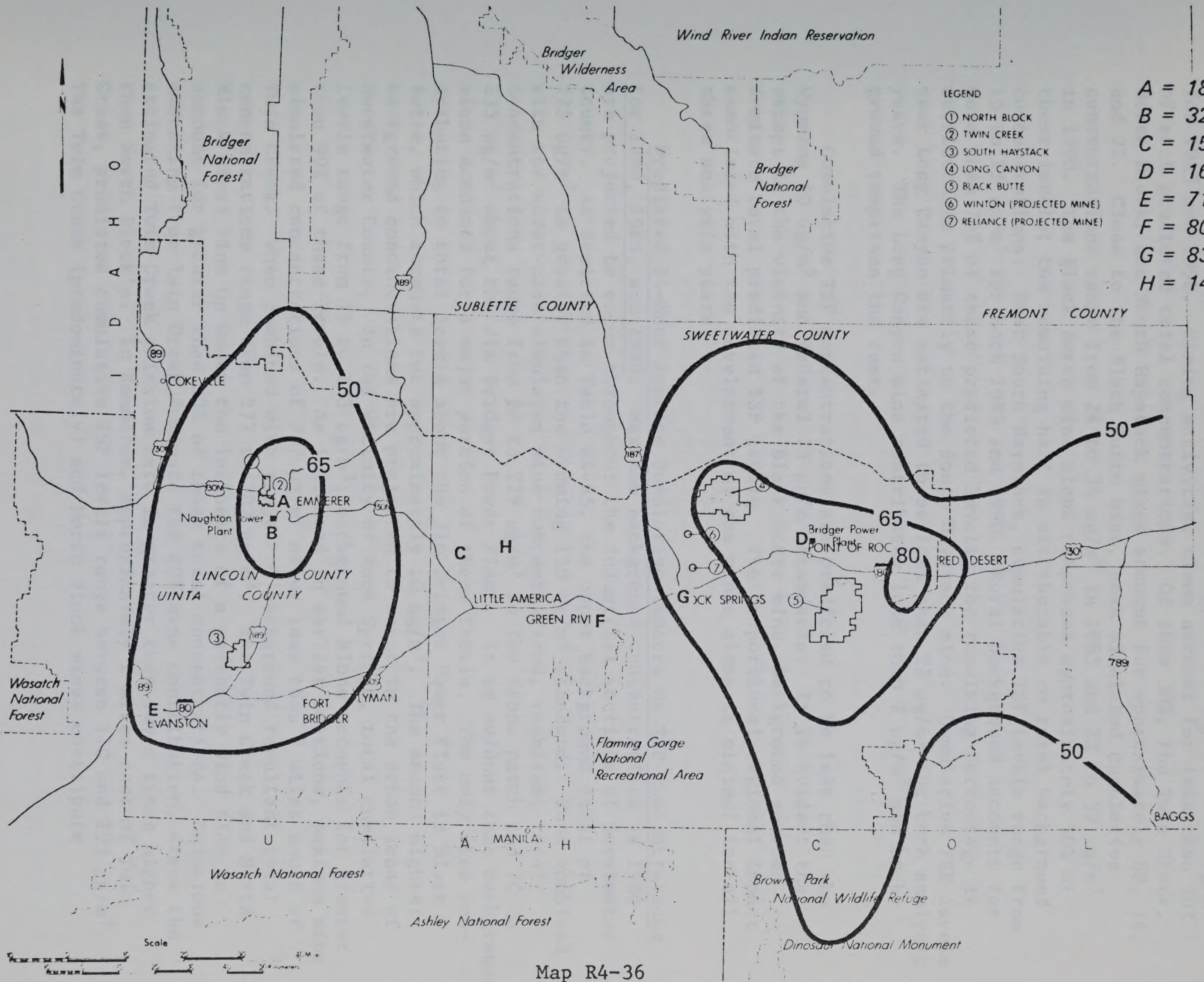
Cumulative 1980 Predicted 24-Hour Average TSP Concentrations ($\mu g/m^3$)


Wind River Indian Reservation
Bridger Wilderness Area
Bridger National Forest
Bridger National Forest
LEGEND
① NORTH BLOCK
② TWIN CREEK
③ SOUTH HAYSTACK
④ LONG CANYON
⑤ BLACK BUTTE
⑥ WINTON (PROJECTED MINE)
⑦ RELIANCE (PROJECTED MINE)
A = 183
B = 384
C = 151
D = 163
E = 70
F = 88
G = 92
H = 150
N
IDAHO
SUBLETTE COUNTY
FREMONT COUNTY
SWEETWATER COUNTY
LINCOLN COUNTY
UINTA COUNTY
COKEVILLE
A EMMERER
Naughton Power Plant
B
C
H
LITTLE AMERICA
GREEN RIV F
G
OCK SPRINGS
D
Bridger Power Plant
POINT OF ROCKS
RED DESERT
E
EVANSTON
FORT BRIDGER
LYMAN
Wasatch National Forest
Wasatch National Forest
Flaming Gorge National Recreational Area
Ashley National Forest
MANILA
UTAH
CO
BAGGS
Browns Park National Wildlife Refuge
Dinosaur National Monument
50
65
50
65
80
95
50
50
189
89
30N
30S
187
30
789
80
Scale
40 Miles
Kilometers

Map R4-35

Cumulative 1985 Predicted 24-Hour Average TSP Concentrations ($\mu g/m^3$)

803288
803346



Wind River Indian Reservation
Bridger Wilderness Area
Bridger National Forest
Bridger National Forest
N
I D A H O
LEGEND
① NORTH BLOCK
② TWIN CREEK
③ SOUTH HAYSTACK
④ LONG CANYON
⑤ BLACK BUTTE
⑥ WINTON (PROJECTED MINE)
⑦ RELIANCE (PROJECTED MINE)
A = 183
B = 326
C = 150
D = 163
E = 71
F = 80
G = 83
H = 148
SUBLETTE COUNTY
FREMONT COUNTY
SWEETWATER COUNTY
LINCOLN COUNTY
UINTA COUNTY
COKEVILLE
KEMMERER
Naughton Power Plant
Bridger Power Plant
POINT OF ROCKS
RED DESERT
LITTLE AMERICA
GREEN RIVER
ROCK SPRINGS
EVANSTON
FORT BRIDGER
LYMAN
BAGGS
MANILA
50
65
80
Wasatch National Forest
Wasatch National Forest
Ashley National Forest
Flaming Gorge National Recreational Area
Browns Park National Wildlife Refuge
Dinosaur National Monument
U T A H
C O L
Scale

Map R4-36

Cumulative 1990 Predicted 24-Hour Average TSP Concentrations (μg/m^3)

greater than 96% to these TSP levels. In the vicinity of Kemmerer, cumulative TSP concentrations range from approximately 25 to 35 μg/m^3 for 1985 and 1990. Mining activities alone account for less than 30% of such predicted total concentrations. Of this 30%, the Twin Creek, North Block, and South Haystack mines account for approximately 82, 16, and 2%. Close to the Black Butte mine, peak simulated cumulative concentrations range from 24 to 34 μg/m^3 in 1985 and 22 to 32 μg/m^3 in 1990. The Black Butte mine alone comprises approximately 50% of these levels; the remaining half is attributable to rural background concentrations. Near South Haystack, cumulative TSP levels range from 15 to 25 μg/m^3 for both 1985 and 1990. Rural background accounts for more than 70% of these predicted levels; the remaining percentage is attributable primarily to the South Haystack mine. Cumulative TSP levels near Long Canyon are estimated to be less than 22 μg/m^3 for both analysis years. The Long Canyon mine contributes less than 2 μg/m^3 and background comprises the rest.

Cumulative TSP concentrations are predicted to be less than the Wyoming 60 μg/m^3 and federal 75 μg/m^3 standards. It is evident that except in the vicinity of the Black Butte mine, background sources dominate total predicted TSP levels. The proportional regional impact associated with the development of the mines alone is minimal for all three analysis years.

Predicted 24-Hour Average Cumulative Impacts on TSP Concentrations for 1980, 1985, and 1990. Maximum background concentrations in 1980 are projected to occur throughout the industrial sections of Sweetwater County. As depicted in Table R4-65, the upper background limit of 225 μg/m^3 is greater than the Wyoming 150 μg/m^3 standard. When combined with the worst-case simulated mine concentrations, resultant total concentrations range from 64 to 229 μg/m^3 in the trona patch and 70 to 235 μg/m^3 about the Jim Bridger Power Plant. It is evident that background alone accounts for a major portion of these totals. The only mine contributing to total levels about the Jim Bridger Power Plant is Black Butte, which accounts for approximately 10 μg/m^3. The second highest background concentrations are projected to occur in the urban areas of Sweetwater County. In the vicinity of Rock Springs, total cumulative levels range from 75 to 135 μg/m^3; background alone accounts for greater than 90% of these levels. As indicated in earlier sections, maximum mine simulated concentrations of 227 μg/m^3 occur less than 2 miles south of Twin Creek. When combined with projected background resultant total concentrations range from 277 to 302 μg/m^3. The Twin Creek and North Block mines line up under the influence of a northerly wind flow to account for greater than 80% of these total concentrations. Emissions emanating from Twin Creek dominate the 80% mine contribution, since the estimated Twin Creek emission rate is greater than seven times higher than North Block's. In Kemmerer, approximately 2 miles east of Twin Creek, predicted cumulative TSP levels range between 170 and 195 μg/m^3. The Twin Creek (predominately) and North Block mines contribute

approximately 120 $\mu g/m^3$ to these levels, indicating that the contribution from background is less than 30%. Within approximately 6 miles north, south, and east of Twin Creek, cumulative TSP levels are predicted to be greater than the Wyoming 150 $\mu g/m^3$ 24-hour average standard, attributable primarily to the Twin Creek mine.

North-northeast of the Black Butte mine, peak mine simulations are about 80 $\mu g/m^3$. When combined with rural background, cumulative TSP concentrations range from 110 to 135 $\mu g/m^3$. It is evident that emissions emanating from Black Butte comprise a major portion of these levels. Maximum mine simulations about South Haystack are also about 80 $\mu g/m^3$. When combined with Uinta County rural background, total predicted TSP levels range from 110 to 130 $\mu g/m^3$ to which the South Haystack mine contributes more than 60%. Cumulative levels about the Long Canyon mine are low, ranging from 55 to 75 $\mu g/m^3$. Long Canyon contributes approximately 10 to 20 $\mu g/m^3$ to such levels; the remainder is attributable to rural background in Sweetwater County. Elsewhere within the ES region, cumulative TSP levels are predicted to be lower than the 150 $\mu g/m^3$ Wyoming standard and become quite low as the distance from the actual mine sites increases. At the same time, background concentrations dominate cumulative SP levels with increasing distance from the sites.

Projected background concentrations for 1985 and 1990 are identical to 1980 with the exception of urban TSP levels in Sweetwater County. Maximum background concentrations ranging from 60 to 225 $\mu g/m^3$ are projected to occur throughout the industrial sectors of Sweetwater County. When combined with ERTAQ simulated mine contributions, cumulative TSP levels range from approximately 66 to 231 $\mu g/m^3$ in the trona patch and 80 to 245 $\mu g/m^3$ near the Jim Bridger Power plant for both analysis years. It is evident that background alone accounts for a major portion of these totals. Balck Butte (accounting for approximately 20 $\mu g/m^3$) is the only mine contributing to cumulative levels are projected to occur in the urban sections of Sweetwater County. In the proximity of Rock Springs, cumulative TSP concentrations are predicted to range from 65 to 120 $\mu g/m^3$ in 1985 and 57 to 157 $\mu g/m^3$ in 1990. Background alone constitutes more than 85% of these levels; the Black Butte mine primarily constitutes the remaining percentage. Maximum ERTAQ-simulated concentrations of 322 and 264 $\mu g/m^3$ occur less than 2 miles south of Twin Creek. When combined with projected background cumulative levels range from 372 to 397 $\mu g/m^3$ in 1985 and 314 to 339 $\mu g/m^3$ in 1990. The Twin Creek and North Block mines influenced by a northerly wind flow line up to account for more than 84% of such total TSP levels. Emissions emanating from Twin Creek in 1985 and 1990 are approximately three times higher than North Block's and, hence, Twin Creek dominates the 84% mine contribution. In Kemmerer, located about 2 miles east of Twin Creek, ranges of 170 to 195 $\mu g/m^3$ are indicative of calculated cumulative impacts for 1985 and 1990. The Twin Creek (predominately) and North Block mines account for 120 $\mu g/m^3$, indicating that the contribution from background is less than 30%. Within approximately a 6 mile radius of Twin Creek, cumulative TSP concentrations are predicted to be greater than the Wyoming 150 $\mu g/m^3$ standard, attributable primarily to the Twin Creek mines.

North-northeast of Black Butte, peak mine simulations are on the order of 120 $\mu g/m^3$ for 1985 and 1990. When combined with Sweetwater County rural background, total predicted ambient levels range from 150 to 175 $\mu g/m^3$, which is treater than the Wyoming standard but less than the national. It is evident that emissions emanating from Black Butte comprise a major portion of these totals. Second highest simulated cumulative TSP levels about Black Butte range from 110 to 135 $\mu g/m^3$, to which the Black Butte mine contributes more than 60%. Maximum mine simulations are also about 80 $\mu g/m^3$ within 3 miles about South Haystack for analysis years 1985 and 1990. When combined with Uinta County rural background, ranges of 110 to 130 $\mu g/m^3$ characterize cumulative TSP levels. The South Haystack mine alone constitutes more than 60% of these total concentrations. Cumulative levels about the Long Canyon mine are similar to 1980, ranging from 55 to 75 $\mu g/m^3$. Long Canyon contributes approximately 10 to 20 $\mu g/m^3$ to such levels, the remainder is attributable to rural background in Sweetwater County. Elsewhere in the ES region, cumulative TSP levels are predicted to be lower than the 150 $\mu g/m^3$ Wyoming standard, and become quite low as distance from the mine sites increases. As in 1980, background levels dominate predicted cumulative levels with increased distance from the mine sites.

Blasting and coal fires are other potential sources of particulate emissions. The impact of these sources is difficult to assess, although the maximum air quality degredation would occur on a very local scale. The cloud of dust produced by blasting would be short-lived, at least compared to the averaging times of the TSP standards (24 hours or greater), so that little contribution to 24-hour levels would be measured inside or outside the mine site. The dust produced would also be initially dispersed to a greater degree by the force of the explosion. Blasting would generally take place during the day, when meteorological characteristics are most favorable for dispersing ground-level pollutants. Coal fires would also occur in spite of measures employed to avoid them. If neglected and allowed to burn out of control for long periods, they could significantly degrade the quality of air, although, on a local scale. Estimates of frequency or quantity of emissions cannot be made. However, due to the high degree of fire control technologies, potential impacts would probably be minimal.

If reclamation fails at one study site because of a natural catastrophe and the area disturbed by mining operations is not revegetated, SP emissions could be greatly increased. These impacts would be primarily local, and regional effects would be minimal.

Region-wide failure of revegetation could occur during a severe drought and, consequently, have a significant impact on ambient air quality. The frequency of severe droughts in southwest Wyoming is approximately three months per year as discussed in Chapter 2. However, the assumption that mulching and planting occur in the fall is inherent in the impact

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results depicted in all maps. Therefore, if the three-month drought period were to occur in the fall, TSP concentrations would be higher than those described in the impact chapter. The likelihood of a fall drought and resultant negative effects on predicted worst-case impacts associated with mining and reclamation processes is unknown.

In general, cumulative impacts on gaseous pollutants (CO, HC, NO_2, and SO_2) are insignificant when compared to standards. Cumulative impacts on CO and HC cannot be quantified due to the lack of monitoring data. However, such total impacts are not expected to significantly differ from impacts associated with the proposed actions alone. Rural background NO_2 and SO_2 levels are quite low; (less than 7% and 2% of state and federal standards, respectively) as discussed in Chapter 2. When combined with concentrations associated with the proposed actions, levels are well below NO_2 and SO_2 standards.

Indirect Air Quality Impacts

Additional air pollutant emissions would result from sources related to the proposed coal development. These indirect sources include:

- new or expanded housing;
- new roadways and increased traffic;
- new or expanded commercial activities;
- expansion of existing power plants; and
- construction activities.

The Jim Bridger and Naughton Power Plants situated in Sweetwater and Lincoln counties, respectively, are the only existing power plants located within the ES region. The expansion of the Jim Bridger Power Plant and the proposed expansion of Naughton Power Plant are expected to increase particulate emissions by 25% and 20%, respectively. Emissions attributable to the remaining indirect sources listed above were based on population growth associated with mining development; population is estimated to increase by 31%, 50%, and 51% in 1980, 1985, and 1990, respectively.

Therefore, ground-level TSP concentrations should increase in all areas but not in a homogeneous spatial pattern. Consequently, a range of baseline (1975) TSP levels typical of rural, industrial, and urban areas was evaluated and projected to the future. These projected baseline values depicted in Table R4-65 are inherent in the background concentrations used to determine the cumulative impacts associated with the most probable level of mining development. A detailed discussion of the derivation of the values is presented in Chapter 2.

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Quantitative impacts of the proposed mines to variations in baseline SO_2 and NO_x concentrations are unknown; however, the contributions from the proposed mines are expected to be negligible. The impact of the indirect sources listed above on baseline SO_2 and NO_x concentrations is discussed in the Chapter 2.

Concluding Statement

The significance of the results presented in the previous sections revolves around several uncertainties inherent in the emission factor and modeling analysis as well as several questions concerning the interpretation of specific standards, the characteristics of the suspended particulate matter and the classification of surrounding lands:

1. From the section entitled "Reliability of Emission Factor Derivation Results," it is evident that the reliability rating of current state-of-the-art fugitive dust emission factors is highly questionable. In fact, the majority of these factors have been rated "poor" according to the U.S. EPA. Such factors are qualified as supportable by best engineering judgment, involving visual observation and judgmental adjustments to results of emissions tests conducted at noncoal mining sources. When combined with the questionable accuracy of input data for the mines, the state-of-the-art fugitive dust emission factor analysis is extremely limited and, therefore, the results obtained in this study are useful only from an order of magnitude or comparative perspective.

2. As detailed in the section entitled "Uncertainties Associated with Modeling of Fugitive Dust Emissions," there are many uncertainties inherent in the modeling analysis. Those model input items casting doubt on the absolute values of predicted TSP concentrations presented in the previous section include:

   - Nonsite-specific meteorology
   - Constant emission rates
   - Source-receptor geometries that do not detail site-specific operational activities
   - Assumption of a 30 foot initial mixing volume for area sources representing the mines
   - Assumption of flat terrain throughout the ES region
   - Lack of a fugitive dust deposition function

3. Primary national air quality standards are intended to protect public health with an adequate margin of safety. Aside from the chemical toxicity of particulate matter, the main parameter affecting human health is particle size. Practically all particles whose diameters are greater than 10 μm are filtered from the air by hairs in the nasal passage and the mucous lining in the nasal cavity and trachea. Particles smaller than about 5 μm in diameter escape the defense mechanisms of the upper respiratory system and enter the lung. Of these, the diameters most effectively retained in the lungs are less than 1.0 μm. Thus, the primary standard should focus on submicron particles. To ensure an adequate margin of safety, the standard should address particles less than 5 μm in diameter.

4. The EPA fugitive dust policy (1977) says that the particulate matter typically found in rural areas, without the impact of major industrial developments, is native soil that for various reasons becomes airborne. It is generally not exposed to potential contaminations by industrial pollutants that commonly occur in urban atmospheres. The toxicity and, consequently, the related health effects of fugitive native soil particulates is probably less than that represented by the ambient health standards. It is therefore possible that the standard may be too restrictive for evaluating the impact of mining, since the majority of dust emissions are from native soil (i.e., overburden, topsoil, and haul roads).

5 Current federal PSD standards are specified as maximum allowable increments to baseline air quality for major emitting facilities. Current regulations do not explicitly define strip-mining operations as major emitting facilities, although they typically emit more than the recommended classification point of 100 tons per year of pollutant. The question revolves around the interpretation of natural as opposed to man-made fugitive dusts. Since natural effects are included in emission estimates (e.g., wind blown dusts), it is unclear what portion of mine-related emissions should be subject to PSD standards.

6. Baseline or "background" air quality levels of TSP employed in the analysis are derived from the few available monitors within the region, which in some cases, are located at significant distances from the mines. It should be noted that especially for particulate matter, the geographical representativeness of a given monitor is often somewhat limited; that is, just because a monitor records high concentrations, it is not necessary to assume that such concentrations occur over a wide geographical area. Therefore, although this assumption was used in the present analysis, the predicted total ambient TSP levels (source and background) at locations where no monitoring is available are questionable.

Probable Cumulative Impacts on Climate

The remainder of this technical presentation specifically addresses the possible meteorological effects resulting from incremental increases in suspended particulates in the atmosphere attributable to the proposed coal development activities in southern Wyoming.

A quantitative estimation of the regional impact on the climate is conjectural at best since the results of various research studies have suggested different, sometimes seemingly contradictory, long-term climatological changes evolving from the introduction of particulates into the atmosphere. Because it is not possible at the present time to quantify inadvertent modification of the climate resulting from man's activities, a few potential effects are discussed on a qualitative basis alone. However, no attempt will be made to rank the importance of the different phenomena.

Suspended Particulates

The most important particulate by-products of coal mines are likely to be dust from soil that is being removed to uncover the coal and carbon dust from the coal itself, which will enter the atmosphere in the form of aerosols. Aerosols may be defined as dispersed solid (or liquid) matter in a gaseous medium. The upper limit of aerosol particle size in the atmosphere is about a 20 µm radius (sedimentation velocity 1 cm/sec) because the residence times of larger particles in the air are relatively small due to their relatively fast sedimentation velocities (Stern 1968). The lower radial limit is of the order of 0.005 µm because of the coagulation of the smaller aerosol particles (Junge 1963). Since the coal mines emit little material in the form of hot plumes, most of it is likely to be ejected mechanically and carried upwards by mechanical turbulence or daytime convection to levels where it can be carried out of the region by the prevailing wind in the lowest 6,000 feet or so. For a mixed layer of this depth and in the absence of diffusion, this implies residence times of up to one hour for 100 µm particles, about five hours for 20 µm particles, and a day for 10 µm particles.

Neglecting the presence of various atmospheric cleansing processes, smaller aerosols can be assumed to stay in the atmosphere for periods comparable to the lifetime of anticyclones and depressions and to have negligible velocity components relative to the air. As this would imply a possible global impact, a comparison of the long range effects on background concentrations attributable to the proposed coal developments with those of natural emissions of suspended material is in order.

Comparison of Global Impact with Natural Varability of Background Concentration

The average area of the proposed coal mines comprises approximately 250 acres (10 km^2). In 1990, five of these mines will produce roughly 12,700 tons of suspended material per year or approximately 1.5 tons per hour.

Dust storms over the North African desert that affected the weather over the Caribbean (Carlson and Prospero 1974) produced much more particulate matter. The area covered by windfields with average speeds over 20 miles per hour is of the order of 10^6 square miles or 3×10^6 km^2. Assuming a rate of production of suspended particulate matter similar to what is produced by the ensemble of proposed coal mines, the total production by a Sahara dust storm would be

$$\frac{\text{Total area covered by dust storm}}{\text{Total area covered by coal mines}} \times 1.5 \text{ ton per hour} =$$

$$\frac{3 \times 10^6 \text{ km}^2}{50 \text{ km}^2} \times 1.5 \text{ tons per hour} = 3.5 \times 10^5 \text{ tons per hour},$$

which is about ten times the total annual production of all coal mines projected for 1990. The production during the lifetime of a Sahara storm may easily be several hundred times the annual production of the projected coal mines. The dust from these storms causes a natural variability in background concentration over the Carribean within a factor of four (Prospero and Carlson 1972). No conclusive statements about the real effect of Sahara dust clouds on the sea surface temperature and climate of the North Atlantic have been made as yet.

The effect of small-scale diffusion of the dispersion of these huge dust clouds (more than 100 miles wide) is likely to be much smaller than that of man-made plumes, and any substantial diffusion is primarily downwards (Prospero and Carlson 1972). Yet, particulate matter leaving Africa with concentrations of 10^3 $\mu g/m^3$, or more, causing visibility to drop to less than a mile (Patterson and Gilette 1976), arrives over the Caribbean with concentrations of the order of 25 $\mu g/m^3$ at the surface and 100 $\mu g/m^3$ between 6,000 and 1,200 feet (Prospero and Carlson 1972).

Hence, a reduction in concentration by a factor of 40 at the surface and a factor of 10 aloft takes place over a distance of roughly 5,000 miles and travel times of several days. The impact of these natural dust clouds on local and global climate are still under investigation, and no definite statements can be made at this time.

It would then seem that, although soil and coal dust produced by mining activity has relatively large concentrations in the 0.1 to 20 μm range, with undisturbed residence times from 1 to 100 days, the rate at

which they are emitted is several orders of magnitude smaller than the natural rates of emission of sand particles over deserts in dust storms, so that the global impact of coal development activities in southern Wyoming is likely to be minute.

Transportation of Aerosols into Organized Convective Storms/Potential Regional Effects

Settling velocities of particles in the 0.1 to 10 μm range are 300 feet per day or less. Such particles can be assumed to move with the velocity of the air in which they are suspended. Therefore, mines located along organized flow into squall-lines and clusters of thunderstorms could add measurably to the number of active condensation nuclei and thus affect the life-history of incipient cumulus convection on the developing side of the storms.

Auer and Komp (1977) found that under conditions of neutral stability in the mixing layer, on fair weather summer days, the concentration of Aitken Condensation Nuclei (ACN)* diminished by a factor of 5 within two to four hours travel time from their source (fossil-fuel power plants), whereafter they became difficult to detect against background concentrations. At that time, typical volume widths were 10 miles at 50 miles from the source. This evidence suggests concentrations of ACN emitted in the inflow region relatively close to a convective storm might be sufficient to affect the precipitation at the time the particulate material arrives at the cloud case.

Diffusion of Aerosols by Atmospheric Dry Convection

Over Wyoming, dry daytime convection may extend over a depth of 6,000 feet or more. In the absence of organized flow into convective storms, aerosols resulting from human activity in the mining area may then be dispersed by atmospheric convective plumes and/or mechanical turbulence. Under those circumstances, the horizontal winds should be rather weak so that the aerosols spend a considerable portion of their settling time relatively close to the mining area. In this case, vertical diffusion takes place at rates comparable to that of horizontal diffusion and transport, particularly so after the nocturnal inversion has been destroyed by small-scale convection from daytime heating (Noonkester and Jensen 1975; Crane et al. 1977). In this case, the depth of the layer in which the particles were originally dispersed suddenly increases two or three-fold. This transition is most likely accompanied by a discrete jump in the size of the dry convective cells, which can eventually lead to cloud formation. This would mean that the

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*Defined by Auer and Komp (1977) as particles ranging from 0.1 to 5.0 μm.

material is dispersed within an hour or so over a volume at least two, three or more times the pre-existing one. Thus, the concentration of potential ACN in the vicinity of the mines is not likely to increase substantially above the background unless a significant dose of effective condensation substrates intrude into the atmosphere.

Aerosol particles can affect meteorological processes in two ways: (1) by altering radiative heat transfer within the atmosphere and (2) by serving as nuclei for the transfer of water vapor to the liquid (condensation) or ice (sublimation) phase.

Aerosols less than 0.1 μm in radius are referred to as Aitken particles and constitute the largest number of particles per unit volume of air in the atmosphere, but contribute the least in terms of total mass. On the contrary, large and giant aerosols (0.1 to 20 μm radius), although relatively few in number, contribute a major proportion to the total mass. In addition, these large particles are most important in scattering solar radiation and in precipitation processes. Furthermore, air quality regulations written for TSP deal with this range of particle size.

Effects on Radiative Transfer

Several authors have suggested an increased burden of aerosol particles could affect the radiation balance by increasing the reflection capacity (albedo) of the earth/atmosphere system, with a resultant temperature decrease at the earth's surface (Rasool and Schneider 1971; Frisken 1971; Barrett et al. 1970). However, other researchers have indicated that determining a net heating or cooling effect at the earth's surface resulting from aerosols depends on the altitude of the suspended particles as well as their absorptivity characteristics (Landsberg 1970; Mitchell 1971; Charlson and Pilat 1969). Mitchell (1971) noted that a general cooling effect could result when the burden of aerosol particles is increased at high altitudes. However, he also suggested that at lower altitudes, if the ratio of the radiation absorbed to the radiation backscattered from the particles is on the order of unity over desert regions and less than half that value over grasslands (prairies), a net heating will occur.

Since surface mining activities should influence the aerosol burden of the lower atmosphere, a warming effect would seem more probable. If realized, warming of the lower atmosphere could conceivably increase its static stability and thus suppress vertical mixing. This could theoretically result in a decrease in precipitation, especially in a region that primarily depends on convective precipitation. However, the physical character of the particles being introduced into atmosphere

because of the mining and related activities and their proportional increase over the natural intrusion of aerosols, two important factors in the determination of the net radiative process are not quantitatively well known. Therefore, both the trend and the magnitude of any inadvertent regional modification caused by the proposed coal development activities remains speculative.

Contribution to the Population of Atmospheric Nuclei*

Heteorogeneous nucleation can occur when water vapor condenses to liquid or sublimates to ice on a particle. It can also occur when a particle initiates the freezing of a liquid droplet. Consequently, aerosol particles effective as heterogeneous nuclei are extremely important in atmospheric precipitation processes. Aerosol particles that are effective in promoting the condensation of water vapor are referred to as cloud condensation nuclei (CCN). Other particles that are effective in initiating the ice phase (either by deposition, contact, or freezing) are called ice nuclei.

Cloud Condensation Nuclei (CCN). The size distribution and nucleation activity of the aerosols introduced from the mining activities could have effects on the precipitation process. Continental air has been shown to have cloud condensation nuclei (CCN) about an order of magnitude greater than maritime air (Hoppel 1973), with a resulting narrower cloud droplet (size) distribution in continental than maritime air (Battan and Reitan 1956). Introduction of additional inefficient CCN could enhance competition for available atmospheric water vapor, thereby resulting in a larger population of monodispersed cloud droplets (Hobbs 1973). One result of this could be lighter precipitation because of the decreased effectiveness of the growth by coalescence of cloud droplets (Hidy 1973).

On the other hand, if the CCN introduced are relatively large and hygroscopic, the opposite process could take place. For example, Eagan, Hobbs and Radke (1974) found CCN concentrations that were four times larger than ambient levels downwind of a kraft pulp mill. These higher CCN concentrations result from the conversion of SO_2 to sulfate particles. In addition, the droplet distribution was broad relative to the distribution in unaffected clouds. A broad droplet distribution would enhance coalescence and, thus, the potential for increased precipitation.

Ice Nuclei. In the mid-latitudes, ice particles play an important role in the growth of precipitation elements in both winter and summer storms, because there is lower equilibrium vapor pressure over ice than water, which results in available ice particles growing at the expense

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*Atmospheric nuclei refers to minute suspended particles that serve as a substrate for the formation of cloud droplets or ice particles.

of cloud droplets (Bergeron-Findeisen process). Consequently, if there were increased atmospheric concentrations of effective ice nucleants, such as Kaolin, a clay-like substance (Byers 1965), resulting from mining and related activities, enhanced precipitation could conceivably occur. But, if the aerosols introduced by mining activities were ineffective ice nuclei, no alteration of precipitation patterns attributable to this process would be expected.

However, for two basic reasons, no quantitative estimate can be made of the net impact of the proposed mining activities on ice nuclei concentrations and subsequent precipitation. First, the structural or chemical characteristics of the aerosol particles that would be introduced, as well as their ability as ice nuclei, is not definitively known at this time. Second, the correlation between the concentration of ice particles and ice nuclei measured in the atmosphere is not as well established as the corresponding relationship between the number of cloud droplets and CCN observed. That is, research has generally shown good agreement between the number of cloud droplets and CCN per unit volume of air (Twomey and Warner 1967; Warner 1969), but similar studies of the relationship between ice nuclei and ice particle concentrations have found discrepancies as large as three to four orders of magnitude (ice nuclei less than ice particles) at the same environmental temperature (Braham 1964; Auer and Veal 1969; Mossop 1970; Mossop et al. 1972).

Summary

The available data do not provide a firm basis for conclusive statements about what role the proposed action mines activities would play in altering the ES region's existing climate over the next fifteen years. Increases in TSP concentration will be above background in the immediate vicinity of the mines, but computations show that it is doubtful whether at distances more than 35 miles from the source these increases could be detected against the natural variability of background concentrations of particulate matter. Near the mines and under certain meteorological conditions atmospheric nuclei could be increased on a local scale, but little can be said with certainty in terms of inadvertent modifications resulting from radiative transfer and precipitation formation because the following variables are not known:

- the chemical composition and physical structure of these particles being introduced;
- the size distribution of the particles being introduced;
- the increase in the number of aerosol particles over the natural intrusion;

- the relative effects on the climate of southern Wyoming of other development activities outside the region of interest and
- no rank of importance of different climatic effects is quantifiable.

Visibility Model

Visibility is subjectively defined as an observer's ability to perceive a distant object against its background. More quantitatively, it is the limiting distance at which the threshold for contrast perception is reached for an observer viewing an ideal object. The ability of an observer to discern distant objects is constrained by the capacity of the intervening atmosphere to absorb and scatter visible light emanating from the object within the field of view. Atmospheric extinction properties and their corresponding effect on visibility degradation depend, in a complicated manner, on the optical nature of the ambient air molecules, aerosols and particulates within the line of sight. Additional anthropogenic sources of particulates, such as those attributable to fugitive dust emissions, reduce visibility downwind from the immediate source area.

Precise evaluation of the degree of visibility degradation requires a knowledge of several source-specific particulate parameters, such as the characteristic number size distribution and optical properties within each size range. Generally, such data vary considerably in time and are usually not available.

In this section basic visibility theory will be summarized and an approach will be described that employs reasonable assumptions to derive an estimate of visibility impact based on projected source-related TSP concentrations. Methodology is outlined both for site-specific and regional cases.

Visibility Theory

The atmosphere's capacity to reduce the contrast of distant objects by a variety of mechanisms is the basis of quantitative evaluation of visibility degradation. For a distant object to be seen there must be some degree of contrast between the object and its background. For an object with intrinsic luminance $B_o(o)$ seen against an extensive background of intrinsic luminance $B_b(o)$, the intrinsic contrast is defined as (Middleton 1958):

$$C(o) = [B_o(o) \quad B_b(o)]/B_b(o) \qquad \text{(R4-37)}$$

Luminance is defined as the intensity in a given direction per unit of projected area (lumens/m^2-steradian). At a distance r, the apparent luminances modified by the effect of the intervening atmosphere are (Duntley 1948):

$$B_{o,b}(r) = B_{o,b}(o) \exp(-\beta r) + B_a [1-\exp(-\beta r)] \qquad \text{(R4-38)}$$

where B_a is the brightness from atmospheric sources, such as scattering of sunlight (a function of solar zenith angle and azimuth)

β is the intervening atmosphere's characteristic extinction coefficient (units: km^{-1})

The apparent contrast at distance r is then:

$$C(r) = C(o) \frac{B_b(o)}{B_b(r)} \exp(-\beta r) \qquad \text{(R4-39)}$$

When viewing against the horizon, $B_b(o) \simeq B_b(r)$.

Standard visual range, V, is defined as that distance where the threshold of contrast perception of the average human eye is reached for a large, black object against the horizon (Malone 1951). For a black object, the intrinsic contrast C(o) = -1.0. Extensive investigations have indicated that although contrast threshold is highly dependent on object size and illumination, the characteristic value approaches 0.02 for large, well-illuminated objects. Employing these assumptions, visibility (visual range in km) is given by (Koschmieder 1924):

$$V = \frac{-\ln(.02)}{\beta} = \frac{3.912}{\beta} \qquad \text{(R4-40)}$$

Several basic assumptions required to yield this simplified form are: (a) the object observed is perfectly black and located at the horizon, (b) the atmosphere between the observer and object is completely homogeneous, (c) the average eye cannot detect an object if its apparent contrast is reduced to less than 2.0%, (d) contributions from multiple scattering may be ignored, and (3) earth curvature and refraction by the atmosphere are negligible. In spite of these simplifications the validity of Equation (R4-40) has been experimentally verified (Horvath and Noll 1969).

Atmospheric Extinction and Background Visibility

Within the limitations of the assumptions previously discussed, visual range is inversely proportional to the atmospheric extinction coefficient β. A number of distinct processes based on essentially

independent mechanisms determine the magnitude of the extinction coefficient. Extinction is defined as the sum of those processes that subtract light intensity from a collimated beam of radiation traversing a given path. These processes are strongly wavelength dependent; however, for the purpose of visibility modeling, a wavelength of 5500Å (0.55 μm) characterizing the maximum sensitivity of light-acclimated (parafoveal) phototopic vision is assumed. Extinction mechanisms can generally be categorized as either absorption or scattering. The mixture of molecules composing air both scatters and absorbs visible light. Ambient, naturally occurring aerosols and particulates of continental or marine origin also scatter and absorb (Deirmendjian 1964). The background extinction coefficient (assuming the absence of local anthropogenic particulate sources) is given by:

$$\beta_{bg} = \beta_{ma} + \beta_{ms} + \beta_{ae}, \qquad \text{(R4-41)}$$

where β_{bg} is the background extinction coefficient (km^{-1})

β_{ma} is the extinction from molecular absorption (km^{-1})

β_{ms} is the extinction from molecular scattering (km^{-1})

β_{ae} is the extinction from ambient aerosols and particulates (km^{-1})

It is noteworthy that the separate contributions cited above are not of equal magnitude. Molecular absorption at 5500Å is primarily from the relatively weak Chappuis bands of ozone (Goody 1964). At sea level the molecular absorption coefficient is about 2.0×10^{-4} km^{-1}. (Absorption by ambient NO_2 is approximately an order of magnitude less.) For a typical Eastern "clear" day with visual range of 23 km, the total extinction coefficient, β_{bg}, is 1.7×10^{-1} km^{-1} (Elterman 1968, 1970). Therefore, the effect of molecular absorption is negligible at visible wavelengths.

Molecular scattering (also called Rayleigh scattering) is next in order of importance to visual range degradation. This process, which is also responsible for the blue color of the sky, is highly wavelength dependent and varies with total atmospheric pressure and temperature. At sea level, the extinction contribution from molecular scattering is approximately 1.2×10^{-2} km^{-1} (McClatchey et al. 1972). In extremely clean atmospheres, molecular scattering limits visibility at great distances.

The largest contribution to background extinction is typically from the background aerosol. The extinction coefficient from this contribution for model background aerosol distributions is about 1.58×10^{-1} km^{-1} (Shettle and Fenn 1976). In most situations, it is the magnitude of the aerosol extinction that is the visibility limiting factor.

- For practical situations where it is desired to evaluate visibility degradation from background levels, a knowledge of the background extinction coefficient is required. Usually, historical records of visibility data exist and it is necessary to estimate the background extinction coefficient using Equation (R4-40):

$$\beta_{bg} = 3.912/V_{bg} \qquad \text{(R4-42)}$$

Evaluation of Visibility Degradation from Fugitive Dust Emissions

Additional sources of particulates above those from the naturally-occurring background levels, such as these attributable to fugitive dust emissions, will reduce visibility downwind from the source area. Visual range in this case will be given by Equation (R4-40), where β is the total extinction coefficient:

$$\beta = \beta_{bg} + \beta_{fd} \qquad \text{(R4-43)}$$

where β_{bg} is the background extinction coefficient (km^{-1})

β_{fd} is the extinction coefficient from the fugitive dust component (km^{-1})

If a visual range from fugitive dust alone is defined in analogy to Equation (R4-42), the resultant total visual range will be:

$$\frac{1}{V} = \frac{1}{V_{bg}} + \frac{1}{V_{fd}} \qquad \text{(R4-44)}$$

Note that the total visual range will always be less than the background value. The departure of the total visual range from the background value will depend on the relative magnitude of the dust component extinction coefficient β_{fd} compared with the background aerosol extinction coefficient β_{ae}.

The extinction coefficient from fugutive dust alone can be evaluated from van de Hulst (1957).

$$\beta_{fd} = \int_{r_1}^{r_2} \pi r^2 Q_E(\alpha,\tilde{m})\, n(r)dr \qquad \text{(R4-45)}$$

where r is the particle radius (μm)

α is the ratio of the particle diameter to the wavelength of light ($= 2\pi r/\lambda$ where $\lambda = 0.55\mu m$)

$\tilde{m}$ is the complex index of refraction of the particles relative to air

Q_E is the ratio of the total cross section for absorption and scattering of light by the particle to its cross-sectional area

$n(r)$ is the number size distribution (the number of particles per unit volume with radii between r and r+dr) ($cm^{-3}\mu m^{-1}$)

This expression assumes that there is a distribution of particles of various sizes within the range $r_1 \leq r \leq r_2$. Extensive measurements indicate that this is generally true for naturally occurring aerosols and particulates (Junge 1958). Evidence also supports this assumption for wind-blown soil (Gillete et al. 1972). The light extinction efficiency factor, Q_E, is a complicated function of the size parameter (α) and the complex index of refraction, $\tilde{m}$, of the fugitive dust material. The complex index of refraction determines the material's optical absorption and scattering properties. The efficiency factor is given by (Mie 1908):

$$Q_E\ (\alpha,\tilde{m}) = \frac{2}{\alpha^2} \sum_{n=1}^{\infty} (2n+1)\ \mathrm{Re}\ (a_n+b_n) \qquad \text{(R4-46)}$$

where a_n, b_n are the complex Mie amplitude functions defined in terms of half integral order Bessel and Hankel functions of the second kind and their derivatives (Kerker 1969). Figure R4-4 illustrates the oscillatory behavior of the efficiency factor as a function of size r (or equivalently of size parameter α). For pure scatterers with typical refractive indices, Q_E can vary from near 0 for very small particles to about 4 when the particle diameter is near the wavelength of the incident light (α=4). For very large particles ($\alpha \rightarrow \infty$), the efficiency factor asymptotes to a limit of 2. As a consequence of the behavior of Q_e, calculations indicate that the size range from $0.1 \leq r \leq 1.0$ μm is most significant in contributing to the extinction coefficient at visible wavelengths (Pueschel and Noll 1967). Particles smaller than 0.05 μm or larger than 5.0 μm contribute very little to light extinction.

For practical reasons, it is desirable to relate the extinction from fugitive dusts directly to the TSP concentrations predicted downwind from the source by diffusion equation analyses. Since the precise form of the number size distribution n(r) is often not available, a compromise technique has been adopted (Ensor and Pilat 1971) that assumes a constant size frequency distribution but weights the contribution to the total mass concentration within each size interval by the TSP concentration. The particulate mass concentration, W($\mu g/m^3$), is given by:

$$W = \frac{4}{3}\pi\rho \int_{r_1}^{r_2} r^3\ n(r)dr \qquad \text{(R4-47)}$$

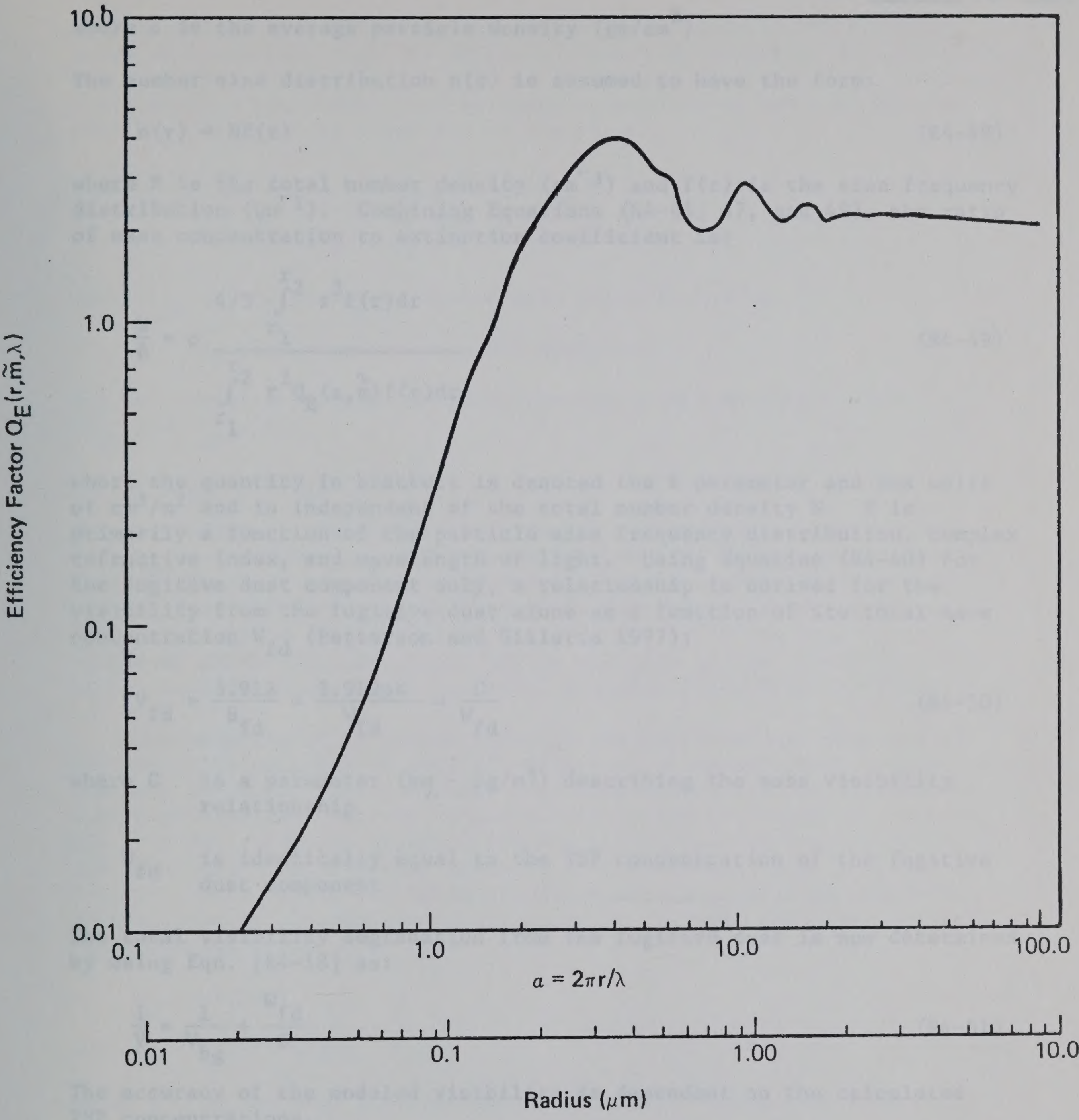


Figure R4-4

Mie Efficiency Factor for Extinction, Q^E as a Function of Radius at Wavelength λ=0.55 μm

where ρ is the average particle density (gm/cm^3).

The number size distribution $n(r)$ is assumed to have the form:

$$n(r) = Nf(r) \qquad \text{(R4-48)}$$

where N is the total number density (cm^{-3}) and $f(r)$ is the size frequency distribution (μm^{-1}). Combining Equations (R4-45, 47, and 48), the ratio of mass concentration to extinction coefficient is:

$$\frac{W}{\beta} = \rho \frac{4/3 \int_{r_1}^{r_2} r^3 f(r)dr}{\int_{r_1}^{r_2} r^2 Q_E(\alpha,\tilde{m}) f(r)dr} \qquad \text{(R4-49)}$$

where the quantity in brackets is denoted the K parameter and has units of cm^3/m^2 and is independent of the total number density N. K is primarily a function of the particle size frequency distribution, complex refractive index, and wavelength of light. Using Equation (R4-40) for the fugitive dust component only, a relationship is derived for the visibility from the fugitive dust alone as a function of its total mass concentration W_{fd} (Patterson and Gillette 1977):

$$V_{fd} = \frac{3.912}{\beta_{fd}} = \frac{3.912\rho K}{W_{fd}} = \frac{C}{W_{fd}} \qquad \text{(R4-50)}$$

where C is a parameter (km - μg/m^3) describing the mass visibility relationship

W_{fd} is identically equal to the TSP concentration of the fugitive dust component

The total visibility degradation from the fugitive dust is now determined by using Eqn. [R4-18] as:

$$\frac{1}{V} = \frac{1}{V_{bg}} + \frac{W_{fd}}{C} \qquad \text{(R4-51)}$$

The accuracy of the modeled visibility is dependent on the calculated TSP concentrations.

Practical Considerations

Practical application of the formulas derived in the previous section requires a basic knowledge of the relevant size frequency distribution of fugitive dust particulates and their corresponding

optical constants. Particle size distribution measurements of wind-blown soil indicate that the optically important particles are those in the size range from $0.62 \leq r \leq 20$ μm (Patterson et al. 1976). Based on these data, a log-normal size frequency distribution has been adopted for the fugitive dust component of the form:

$$f(r) = \frac{1}{r\sqrt{2\pi}\,\ln\sigma_g} \exp\left[\frac{-1}{2}\left(\frac{\ln r/r_{gn}}{\ln \sigma_g}\right)^2\right], \qquad \text{(R4-52)}$$

where r_{gn} is the geometric number mean particle radius

σ_g is the geometric standard deviation

The relationship between the geometric number and mass mean radii (r_{gn} and r_{gw}) is:

$$\ln r_{gn} = \ln r_{gw} - 3\ln^2\sigma_g \qquad \text{(R4-53)}$$

For the optically significant size range, a distribution was selected with $r_{gw} = 3.0$ μm and $\sigma_g = 2$. Not all of the TSP from fugitive dust falls within this size range, however, as the measurements suggest a bimodel distribution with one peak at larger radii. Based on measurements of fugitive dust from coal mines (PEDCo 1977) and road sources (Jutze et al. 1977), 60% of the TSP is assigned to the optically significant mode (a conservative estimate, especially far from the mines).

Furthermore, it is recognized that the fugitive dust from mining activities is composed of optically distinct components such as coal dust (carbon) and soil. It is assumed that both components populate the same size distribution. However, their relative mass fractions are computed based on site specific emission factors for various mining operations and processes. For regional analysis an overall mean mass fraction is derived. Thus, given the ERTAQ-simulated TSP concentration down wind from the source, the mass concentrations of fugitive coal dust and soil, respectively, are:

$$W_c = gf(\text{TSP}) \qquad \text{(R4-54a)}$$

and $$W_s = g(1-f)\ (\text{TSP}) \qquad \text{(R4-54b)}$$

where g is the mass fraction in the optically significant size range ($g = 0.60$)

f is the mass fraction of coal dust alone

Separate C factors for coal and soil are computed using the ERT VISOP program and the appropriate complex indices of refraction and densities. The VISOP program is a computer code developed at ERT for the analysis

of the wavelength-dependent optical properties of a log-normal size distribution of aerosol particles. These values are summarized in Table R4-66. Expressed in terms of the individual mass concentration for coal and soil, Eqns. [R4-54a,b], the visual range from fugitive dust (Eqn. [R4-50]) is:

$$V_{fd} = \frac{C_s C_c}{0.60(TSP)} \left[(1-f)C_c + fC_s\right]^{-1} \qquad \text{(R4-55)}$$

The total visibility degraded by fugitive dust is evaluated using Eqn. (R4-54) to give:

$$\frac{1}{V} = \frac{1}{V_{bg}} + \frac{0.60(TSP)}{C_s C_c} \left[(1-f)C_c + fC_s\right] \qquad \text{(R4 56)}$$

For the chosen size parameters and optical constants (Table R4-66), the computed C values for coal and soil are 1.086×10^4 and 1.342×10^4 km - $\mu g/m^3$, respectively. Experimental C values based on simultaneous measurements of visibility and mass concentration of airborne dust yield values between 1.1×10^4 and 2.0×10^4 km - $\mu g/m^3$ (Patterson and Gillette 1977), which are consistent with the computed results. A comparison between the measured and computed visibility versus mass concentration relationship is illustrated in Figure R4-5. Data are based on measurements of airborne soil particles in reduced visibility situations (Patterson and Gillette 1977). The model calculations are performed using the appropriate C value for soil ($f = 0.0$) and assuming a g factor of 0.6. A background visibility of 40 km is assumed. (The visibilities are not sensitive to the background value in this situation.) Computed visibilities agree well with the measurements (within a confidence factor of approximately 2) over these orders of magnitude in mass concentration. Variation of C values for coal and soil with log normal shape parameters r_{gw} and σ_g is illustrated in Figures R4-6 and R4-7, respectively. In general, the visibility for a given TSP concentration decreases significantly as more particles are found in the optically significant size range. Figures R4-8 and R4-9 illustrate the application of Eqn. (R4-30) for coal dust only ($f = 1.0$) and soil dust only ($f = 0.0$), respectively. Plotted are background visibility, V_{bg}, versus total visibility, V, for various levels of fugitive dust loading.

Comparison can be made between the results of Eqn. (R4-30) and previous mass-visibility relationships. Charlson (1969) has shown that one such mass-visibility relationship in a polluted urban atmosphere is given by:

$$V = \frac{1120}{(TSP)} \ \text{mi-}\mu g/m^3 \qquad \text{(R4-57)}$$

In a later study in a rural, low pollution area (Ettinger and Royer 1972) a similar relationship was found:

$$V = \frac{24.0}{0.2 + (0.01 + 0.01)\ (TSP) - 0.003} \ \text{mi - } \mu g/m^3 \qquad \text{(R4-58)}$$

TABLE R4-66

COMPLEX INDEX OF REFRACTION, DENSITY, AND SIZE DISTRIBUTION PARAMETERS FOR C FACTOR COMPUTATION

	Complex Index of Refraction, $\tilde{m}$	Density (gm/cm^3)	Size Parameters	
			r_{gw} (μm)	σ_g
Coal Dust (carbon)	1.960-0.660 i (Twitty and Weinman 1971)	2.0	3.0	2.0
Soil Dust	1.525-0.005 i (Grams et al. 1974)	2.5	3.0	2.0

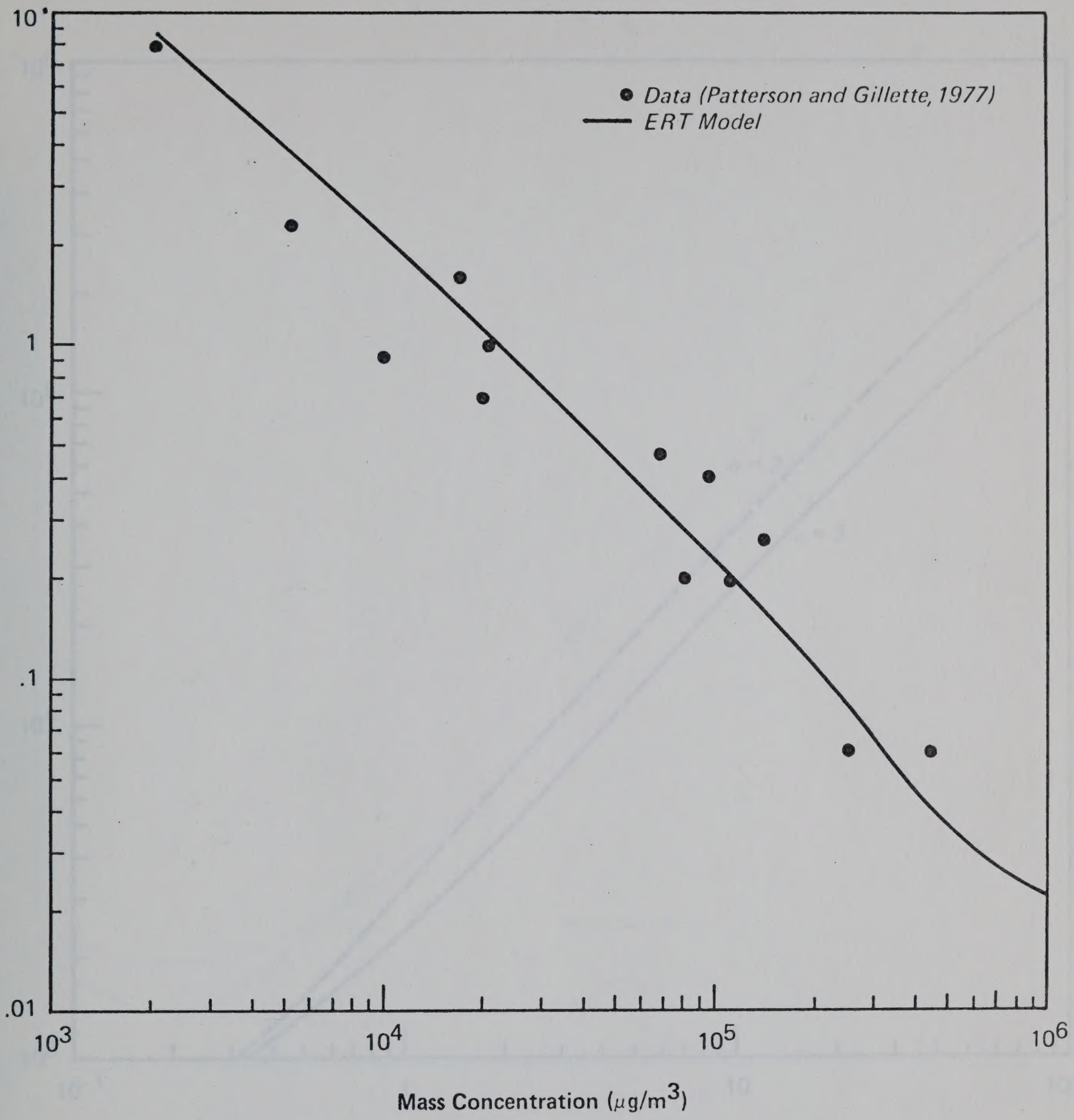


Figure R4-5

Comparison Between Measured and Computed Visibility Versus Mass Concentration for Airborne Soil

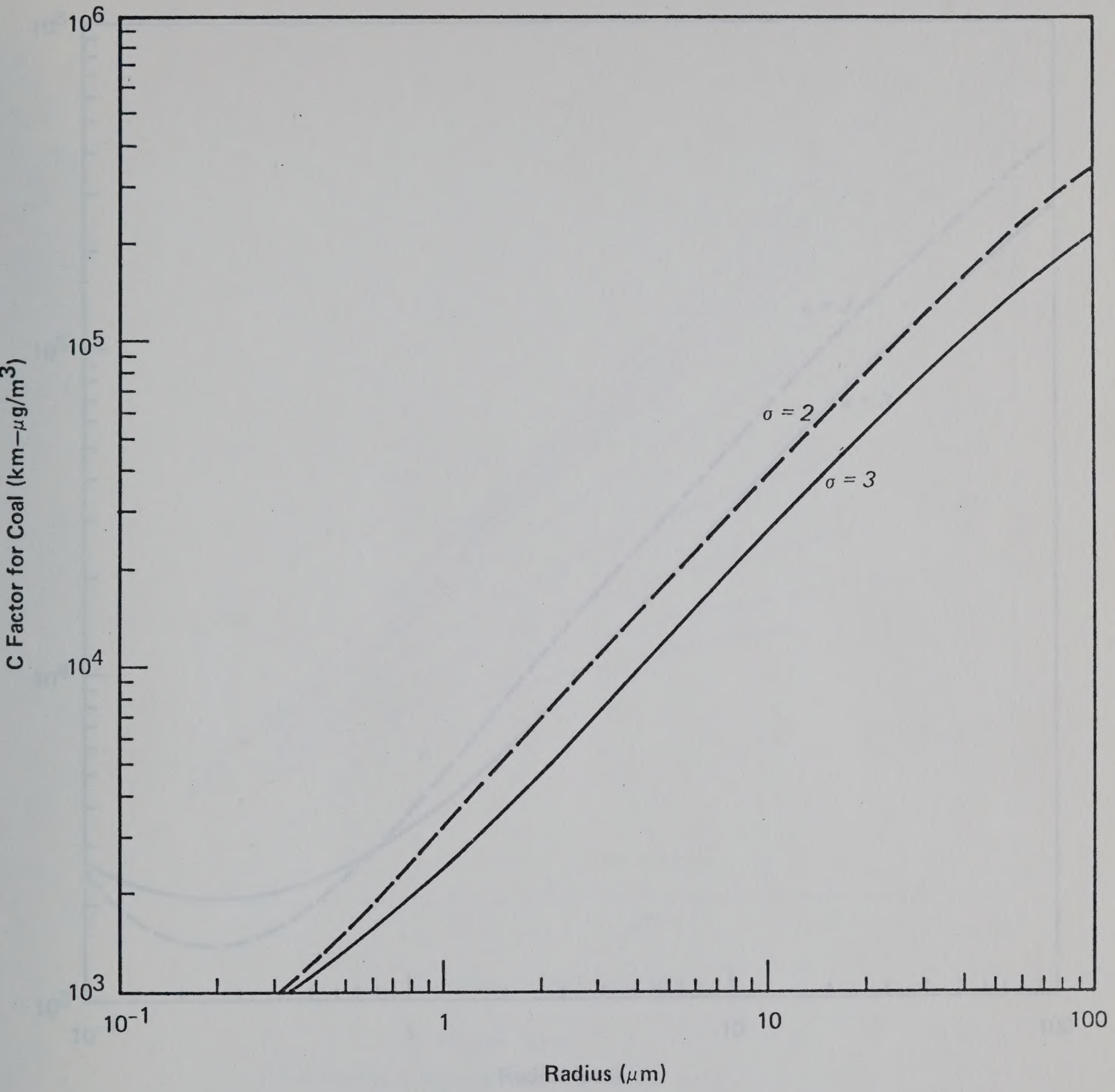


Figure R4-6

Variation of C Factors for Coal with
Log Normal Size Distribution Shape
Parameters

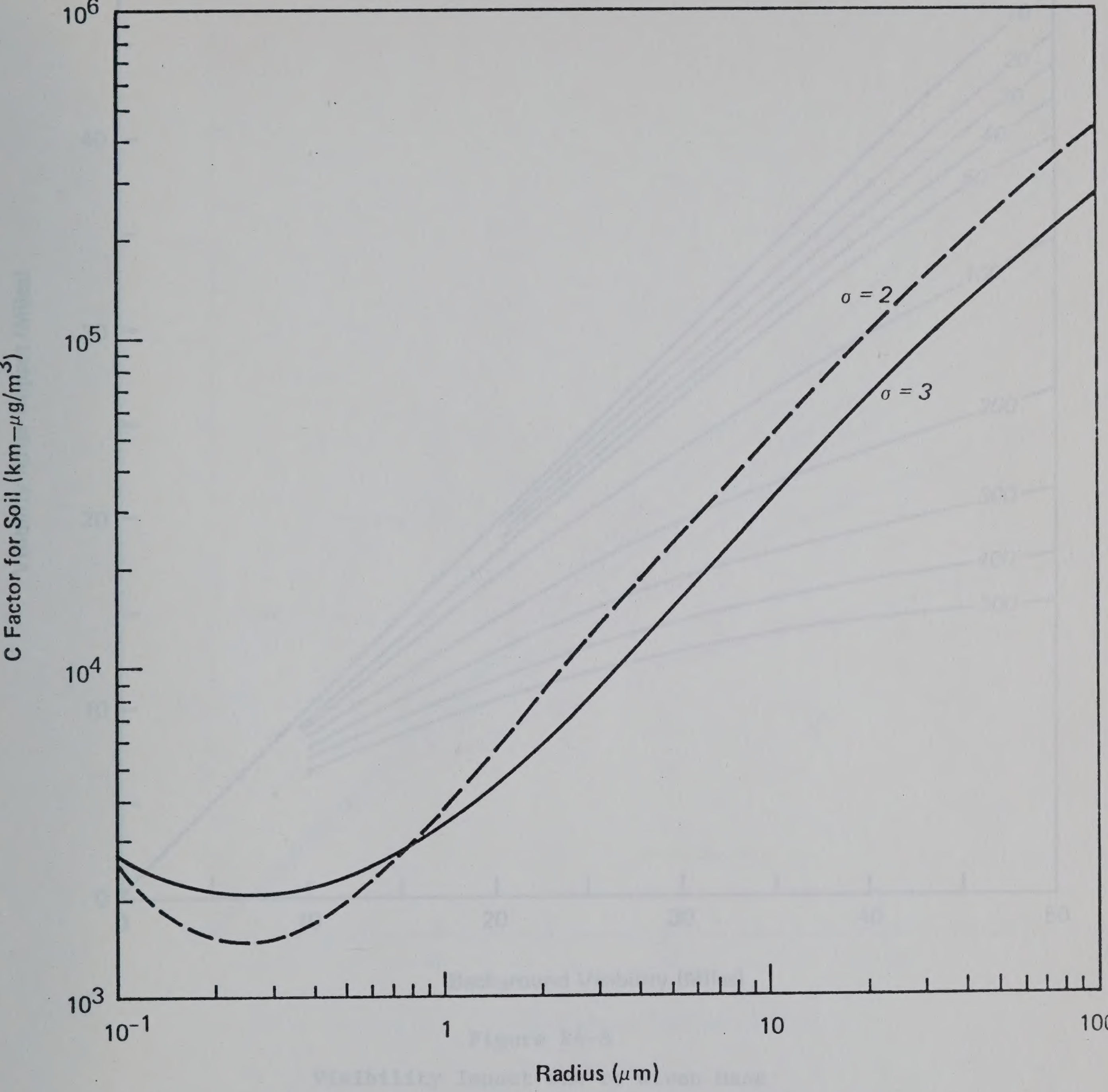


Figure R4-7

Variation of C Factors for Soil with Log Normal Size Distribution Shape Parameters

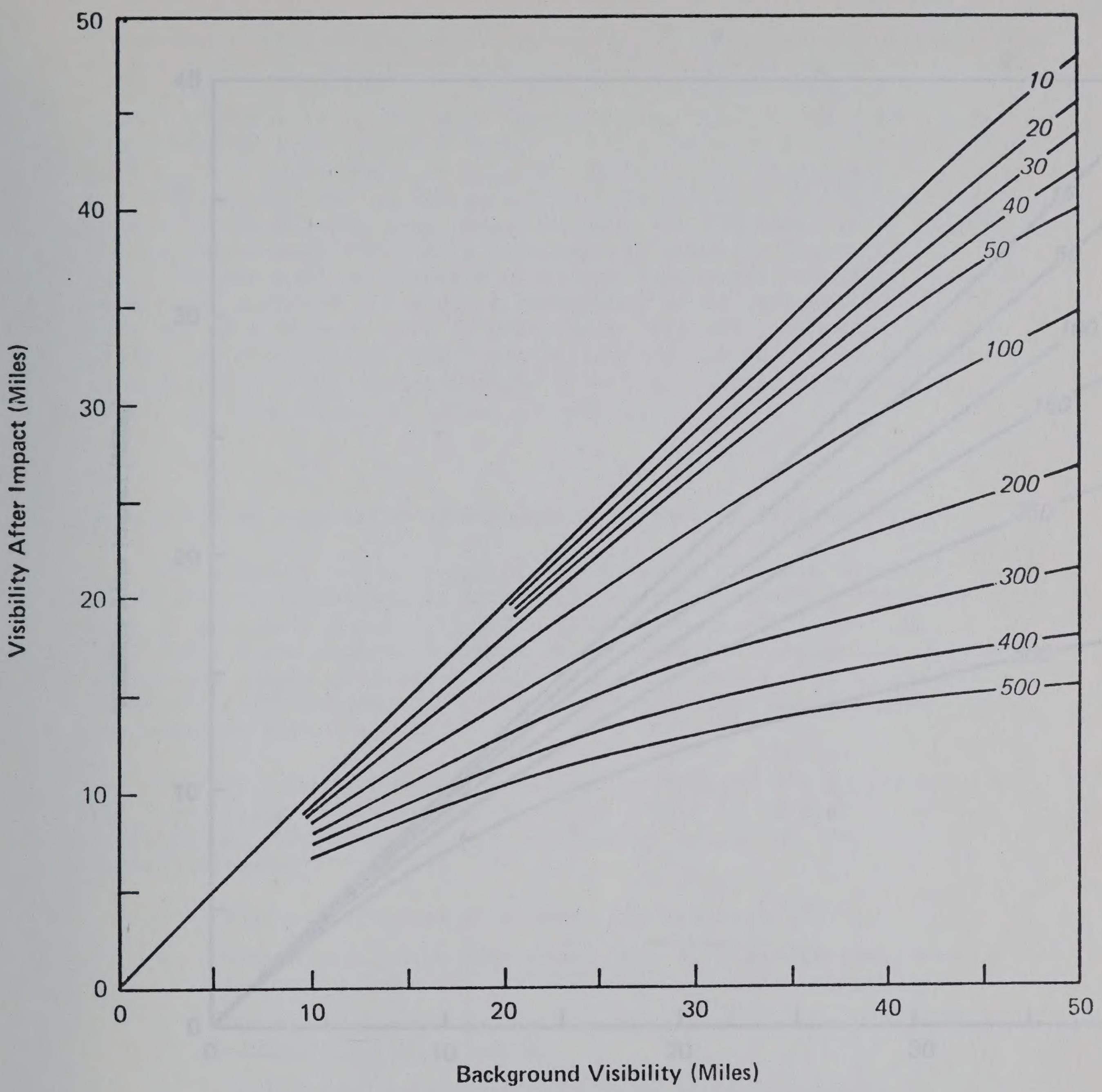


Figure R4-8

Visibility Impact Due to Given Mass Concentration of Coal Dust for Specified Background Visibility

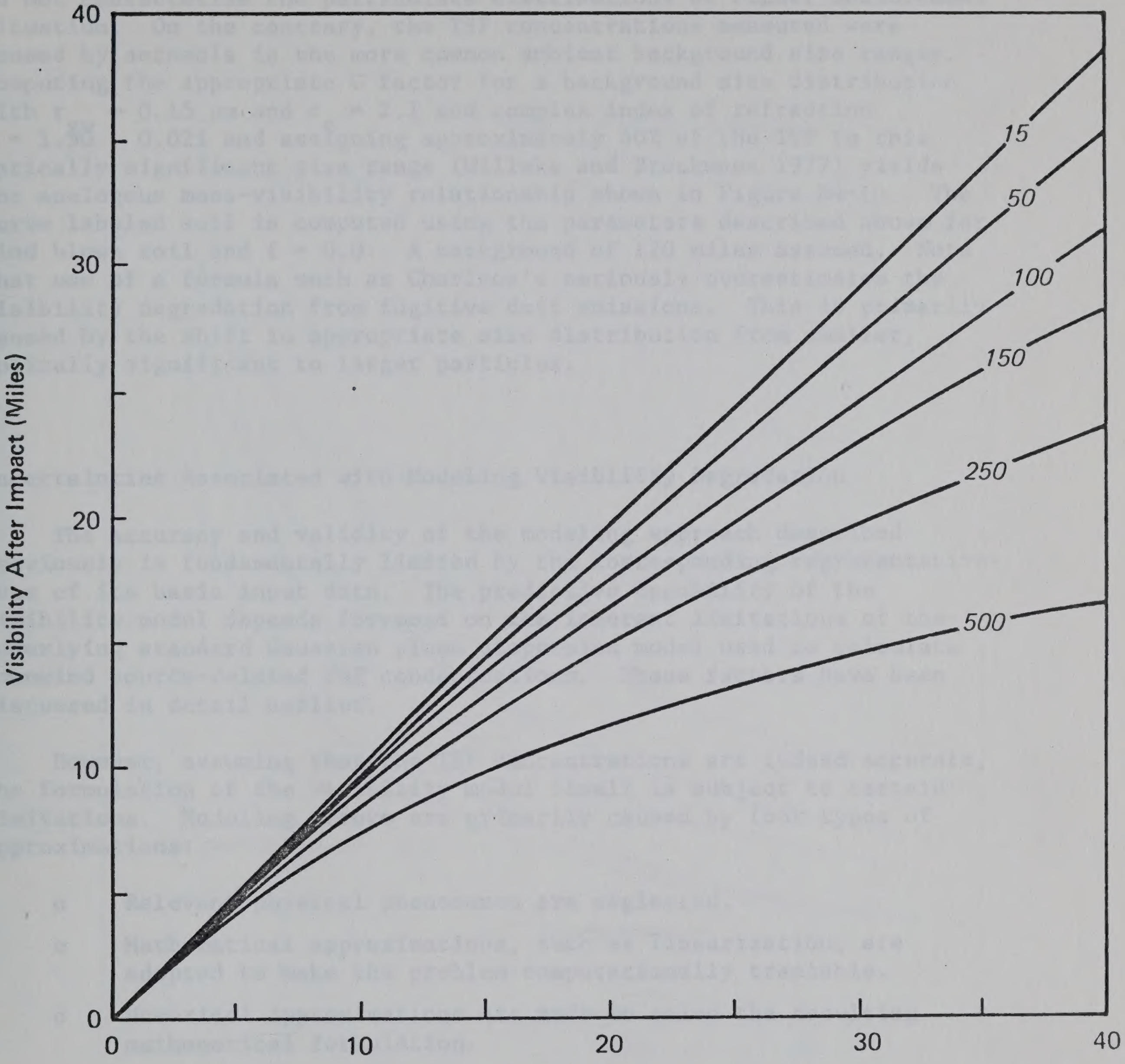


Figure R4-9

Visibility Import Due to Given Mass Concentration of Airborne Soil for Specified Background Visibility

These are plotted in Figure R4-10. It is noteworthy that fugitive dusts do not characterize the particulate distributions of either measurement situation. On the contrary, the TSP concentrations measured were caused by aerosols in the more common ambient background size ranges. Computing the appropriate C factor for a background size distribution with $r_{gw} = 0.15$ µm and $\sigma_g = 2.1$ and complex index of refraction $\underset{\sim}{m} = 1.50 - 0.02i$ and assigning approximately 40% of the TSP to this optically significant size range (Willeke and Brockmann 1977) yields the analogous mass-visibility relationship shown in Figure R4-10. The curve labeled soil is computed using the parameters described above for wind blown soil and f = 0.0. A background of 120 miles assumed. Note that use of a formula such as Charlson's seriously overestimates the visibility degradation from fugitive dust emissions. This is primarily caused by the shift in appropriate size distribution from smaller, optically significant to larger particles.

Uncertainties Associated with Modeling Visibility Degradation

The accuracy and validity of the modeling approach described previously is fundamentally limited by the corresponding representativeness of its basic input data. The predictive capability of the visibility model depends foremost on the inherent limitations of the underlying standard Gaussian plume dispersion model used to calculate downwind source-related TSP concentrations. These factors have been discussed in detail earlier.

However, assuming that the TSP concentrations are indeed accurate, the formulation of the visibility model itself is subject to certain limitations. Modeling errors are primarily caused by four types of approximations:

- Relevant physical phenonemon are neglected.
- Mathematical approximations, such as linearization, are adopted to make the problem computationally tractable.
- Numerical approximations are made to solve the resulting mathematical formulation.
- Statistical errors are introduced by uncertainties in input parameters and boundary conditions.

The most obvious physical phenomenon neglected in the fugitive dust formulation is realistic fallout from settling. This is a direct consequence of the conservation of mass required by the plume model. However, the visibility relationship derived is self-consistent due to two physical results: (a) the smaller size particles (0.1 to 1.0 µm) are most optically active and effective in reducing visibility, and (b) the larger size particles are predominantly subject to fallout.

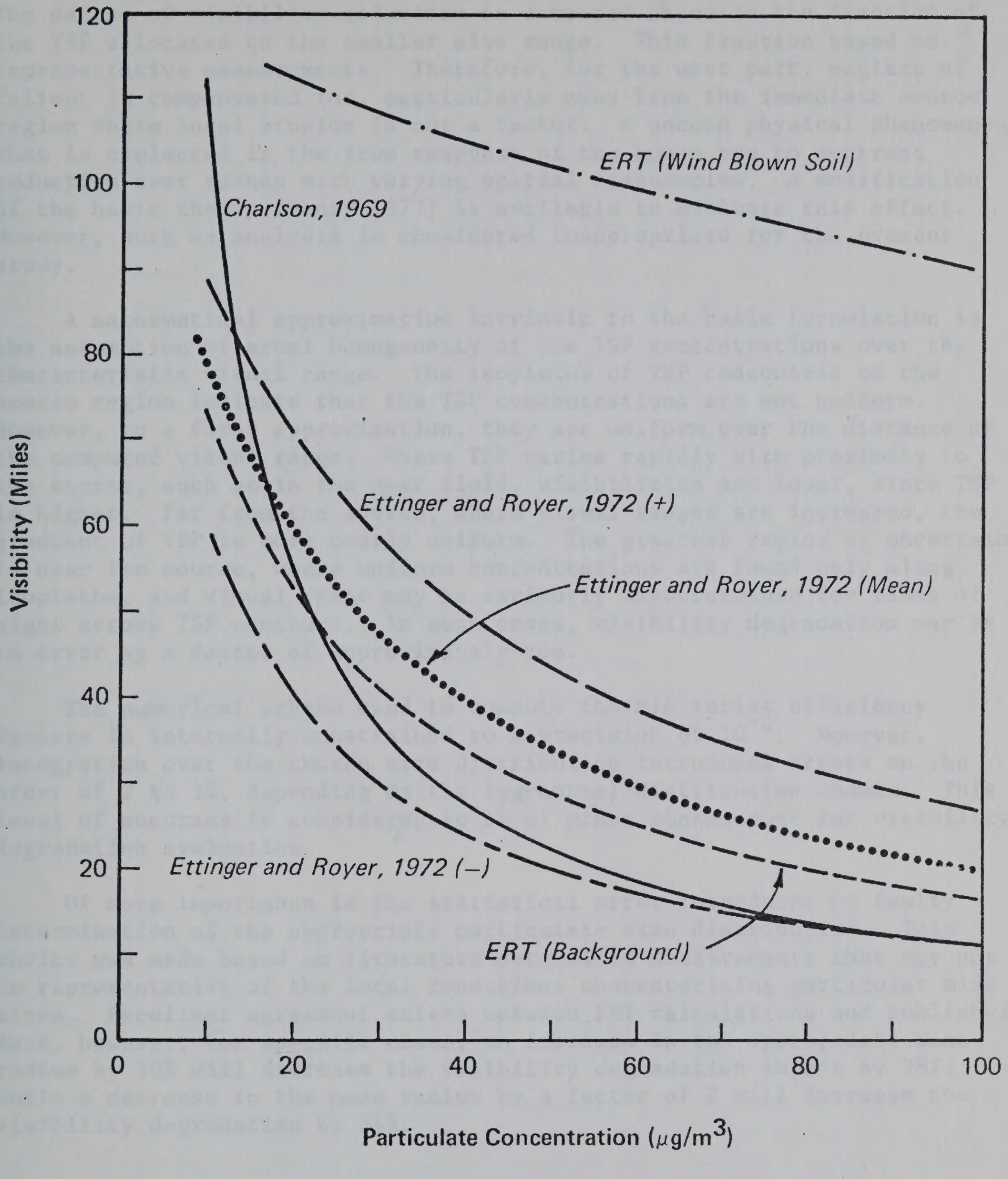


Figure R4-10

Comparison of Literature Visibility Versus Mass Concentration Relationships

The degree of visibility reduction is computed based on the fraction of the TSP allocated to the smaller size range. This fraction based on representative measurements. Therefore, for the most part, neglect of fallout is compensated for, particularly away from the immediate source region where local erosion is not a factor. A second physical phenomenen that is neglected is the true response of the human eye to contrast reduction over scenes with varying spatial frequencies. A modification of the basic theory (Henry 1977) is available to evaluate this effect. However, such an analysis is considered inappropriate for the present study.

A mathematical approximation intrinsic to the basic formulation is the assumption of areal homogeneity of the TSP concentrations over the characteristic visual range. The isopleths of TSP concentric to the source region indicate that the TSP concentrations are not uniform. However, to a first approximation, they are uniform over the distance of the computed visual range. Where TSP varies rapidly with proximity to the source, such as in the near field, visibilities are lower, since TSP is higher. Far from the source, where visual ranges are increased, the gradient of TSP is more nearly uniform. The greatest region of uncertainty is near the source, where uniform concentrations are found only along isopleths, and visual range may be seriously misdetermined for lines of sight across TSP contours. In such cases, visibility degradation may be in error by a factor of approximately two.

The numerical scheme used to compute the Mie series efficiency factors is internally constrained to a precision of 10^{-4}. However, integration over the chosen size distribution introduces errors on the order of 2 to 3%, depending on the log-normal distribution chosen. This level of accuracy is considered to be of minor consequence for visibility degradation evaluation.

Of more importance is the statistical error introduced by faulty determination of the appropriate particulate size distribution. This choice was made based on literature-determined measurements that may not be representative of the local conditions characterizing particular mine sites. Excellent agreement exists between ERT calculations and published data, however, for specific cases, an increase in the appropriate mean radius by 50% will decrease the visibility degradation impact by 38%, while a decrease in the mean radius by a factor of 2 will increase the visibility degradation by 34%.

Regional Results

Using the relationship between visibility and fugitive dust derived in the previous section and the worst-case, 24-hour SP concentrations shown in Maps R4-16 through R4-30, degradation of visibility throughout

the ES region can be addressed. In general, isopleths of visibility and TSP are not coincident and Eqn. (R4-30) is strictly valid only for uniform aerosol distributions. It is assumed, however, that sufficiently far from particular sources, the TSP distribution is relatively homogeneous over the distance of the prevailing visibilities. Close to sources where the TSP gradient is greater, use of the visibility relationship will be valid only for observer lines of sight parallel to TSP isopleths. Visibility is overestimated when looking towards the source and underestimated when looking away from the source. The years 1980, 1985, and 1990 are examined. The coal and soil mass fractions for each mine considered in the analysis were determined from the annual average emission rates and averaged to obtain annual mean mass fractions of coal. (That is, the proportion by weight of total annual particulates emitted, which is coal dust). These mean mass fractions of coal for the years cited are 0.08, 0.27, and 0.27, respectively.

In conjunction with current visibility observations, regional background visibilities were determined to be 40 miles for each year. Unaccounted for factors, such as increased levels of regional sulfate or nitrate aerosols, may significantly alter the projected assumed background visibilities and the reader is cautioned to be aware of such anomolies.

For brevity, specific aspects of the visibility degradation corresponding to the projected TSP distribution are addressed. These include the minimum visibility predicted by the maximum predicted pollutant concentrations within the ES region and the visibility corresponding to the predicted levels of 20 $\mu g/m^3$. An examination of the TSP maps indicates that most of the ES region has predicted TSP concentrations from fugitive dust sources less than this value. Additionally, Class I areas (Bridger Wilderness Area) and potential Class I areas (Flaming Gorge and Fossil Butte) are examined for significant degradation of visibility.

For 1980, worst-case, 24-hour SP concentrations attain values as high as 227 $\mu g/m^3$ in the vicinity of the proposed North Block and Twin Creek mines. This corresponds to a visibility of 24 miles, when assuming a background of 40 miles. Most of the region, however, is characterized by predicted levels less than 20 $\mu g/m^3$, which corresponds to a visibility of 37.8 miles (a reduction of 2.2 miles from the background).

Concentrations in the Bridger Wilderness Area (Class I) are about 1 $\mu g/m^3$. This level of TSP yields a visibility of 39.9 miles for a reduction of less than 0.3% from the background. In the vicinity of Flaming Gorge National Recreational Area (Class II), TSP values are between 2 and 4 $\mu g/m^3$, giving visibilities of 39.5 miles (visibility degradation 1.2%). At Fossil Butte, concentrations are approximately 20 $\mu g/m^3$. The computed visibility and visibility degradation are 37.8 miles and 5.5%, respectively.

For 1985, worst-case 24-hour SP concentrations attain values as high as 322 $\mu g/m^3$ in the vicinity of the proposed North Block and Twin Creek mines. This corresponds to a visibility of 20.1 miles, assuming a

background of 40 miles. Most of the region, however, is 20 μg/m^3, which corresponds to a visibility of 37.7 miles, (a reduction of 2.3 miles from the background).

Concentrations in the Bridger Wilderness Area (Class I) are between 1 and 2 μg/m^3. This level of SP yields a visibility of 39.8 miles for a reduction of less than 0.7% from the background. In the vicinity of Flaming Gorge National Recreational Area (Class II), SP values are between 4 and 5 μg/m^3, giving visibilities of 39.4 miles (visibility degradation 1.5%). At Fossil Butte, concentrations are approximately 32 μg/m^3. The computed visibility and visibility degradation are 36.4 miles and 8.9%, respectively.

For 1990, worst-case 24-hour SP concentrations attain values as high as 264 μg/m^3 in the vicinity of the proposed North Block and Twin Creek mines. This corresponds to a visibility of 22.1 miles, assuming a background of 40 miles. Most of the region, however, is characterized by predicted levels less than 20 μg/m^3, which corresponds to a visibility of 37.7 miles (a reduction of 2.3 miles from the background).

Concentrations in the Bridger Wilderness Area (Class I) are about 1 μg/m^3. This level of SP yields a visibility of 39.9 miles for a reduction of less than 0.3% from the background. In the vicinity of Flaming Gorge National Recreational Area (Class II), SP values are between 3 and 4 μg/m^3, giving visibilities of 39.5 miles (visibility degradation 1.3%). At Fossil Butte, concentrations are approximately 25 μg/m^3. The computed visibility and visibility degradation are 37.2 miles and 7.1%, respectively.

Site-Specific Computations

The methodology described in the previous section is generally applicable to analysis of regional visibility degradation. For the site specific cases, however, a modification of the basic theory is required to account for the inhomogeneity with respect to particulate loading of the horizontal atmospheric path when observing through a wind-blown plume. The assumed geometry of observation is illustrated in Figure R4-11. The hypothetical observer is positioned a distance X_i downwind such that the line of sight is perpendicular to the average wind direction across the plume within a 22.5° sector. The width of the plume Y_i at distance X_i downwind is simply:

$$Y_i = 2X_i \tan 11.25° \qquad \text{(R4-59)}$$

The ERTAQ-based downwind SP concentrations are partitioned by mass into coal soil fractions as described in the previous section and the visibility in the plume at distance X_i downwind is given (from Eqn. (R4-55) by:

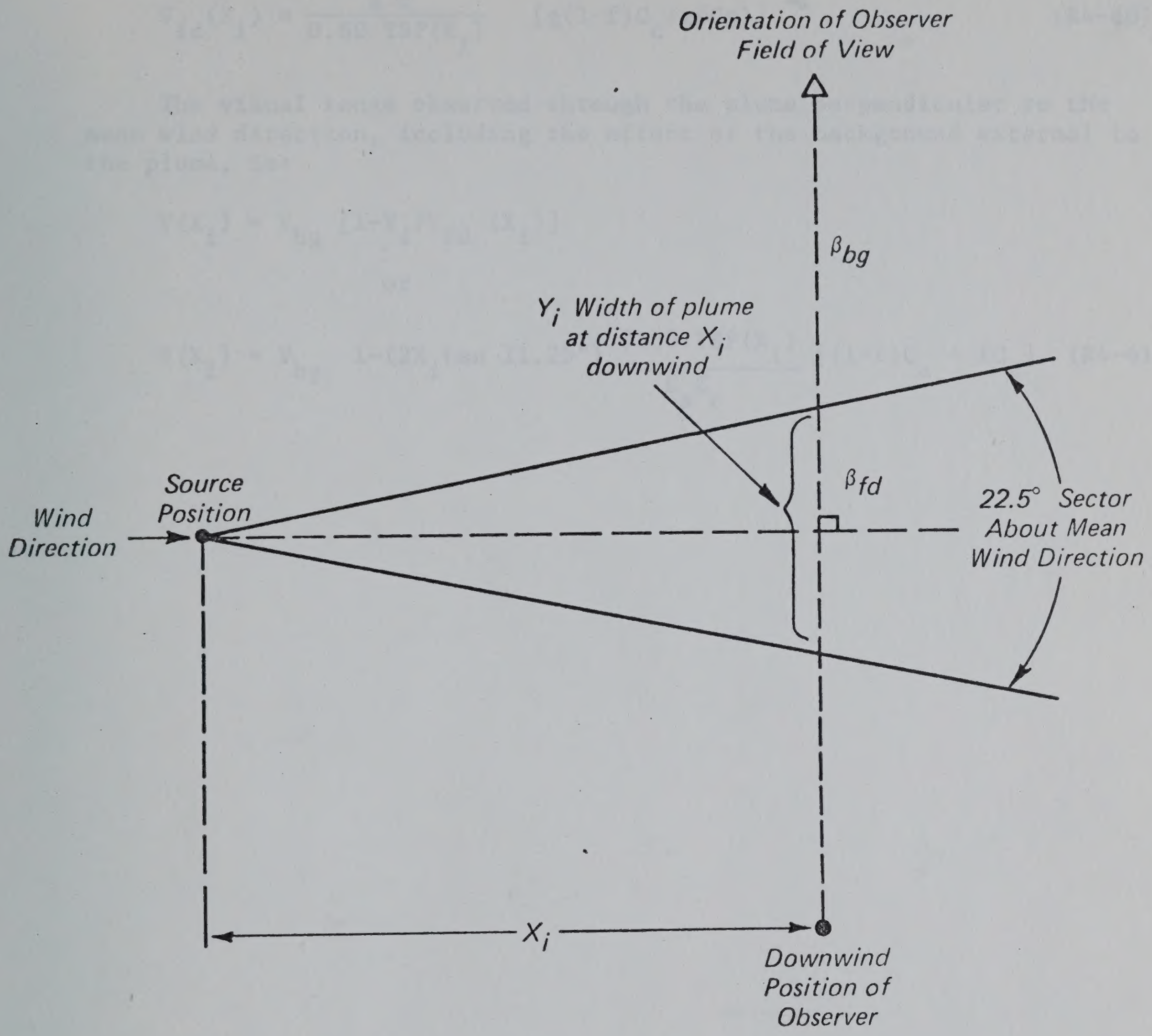

Orientation of Observer Field of View
β_{bg}
Y_i Width of plume at distance X_i downwind
β_{fd}
22.5° Sector About Mean Wind Direction
Source Position
Wind Direction
X_i
Downwind Position of Observer

Figure R4-11

Geometry of Observation Through Plume

$$V_{fd}(X_i) = \frac{C_s C_c}{0.60\ TSP(X_i)} \quad [g(1-f)C_c + gfCs)]^{-1} \qquad \text{(R4-60)}$$

The visual range observed through the plume perpendicular to the mean wind direction, including the effect of the background external to the plume, is:

$$V(X_i) = V_{bg}\ [1 - Y_i/V_{fd}\ (X_i)]$$

or

$$V(X_i) = V_{bg}\ \ 1-(2X_i \tan 11.25°)\ \frac{0.60\ TSP(X_i)}{C_s C_c}\ [(1-f)C_c + fC_s] \qquad \text{(R4-61)}$$

AIR QUALITY ALTERNATIVES TO THE PROPOSED ACTION

This chapter investigates the impacts on TSP and gaseous pollutant concentrations as well as climatic and visibility effects resulting from two alternative levels of mining development in the ES region. The first alternative, the no action or low-level scenario, considers impacts associated with background and the operation of two private mines (Winton and Reliance) that are not active in 1980. Therefore, the impact results presented for the low-level scenario address analysis years 1985 and 1990. The second alternative, the high-level scenario, along with background levels, consists of the five proposed and two projected mines considered in Chapter 4, three existing leases without proposed mine plans, and three potential mining "areas of interest." The latter six mines are not operational in 1980; therefore, impact results for 1980 are equivalent to those presented in Chapter 4. Consequently, impacts associated with the high-level scenario in this chapter address analysis years 1985 and 1990. The locations of all of the mine sites are depicted in subsequent subsections.

Fugitive Dust Emission Factors and Modeling Techniques

The methods used to determine fugitive dust emissions emanating from the coal mines considered in the alternative scenarios, as well as meteorological data and modeling techniques, are equivalent to those presented in Chapter 4. Particulate emission rates, as well as the acres disturbed, used to determine the size of the area sources in ERTAQ are presented in Tables R8-1 and R8-2 for the three existing leases without proposed mine plans and the three potential mining areas of interest. These parameters for all other mines evaluated herein are presented in Chapter 4.

The emission rates for the six underground mines depicted in Table R8-1 were calculated as follows:

$$E = CP \cdot EF \cdot K \tag{R8-1}$$

where

E is the total emission rate in tons per year

CP is the coal production in tons per year

EF is the emission factor of 0.31 for underground mines with controls in pounds per ton

K is the constant value of 1/2000 to convert the equation to appropriate units of tons per year

TABLE R8-1

PARTICULATE EMISSION RATES BASED ON TOTAL COAL PRODUCTION FOR 1985 AND 1990

Projected Mines Map Reference Number (MRN)*	Coal Production (million tons per year)	Emission Rate (tons per year)
8	2.5	83
9	2.5	79
10	2.5	225
11	1.9	56
12	1.9	147
13	1.9	91

*Refers to mine numbers indicated on Map R8-1. MRN-8 to MRN-10 correspond to the three mine "areas of interest" and MRN-11 through MRN-13 correspond to the three existing leases without mine proposals. Throughout this report, these six mines will be referred to as MRN-8 through MRN-13.

TABLE R8-2

ACRES DISTURBED EQUALS SIZE OF AREA SOURCE IN ERTAQ MODELING

	1985	1990
MRN-8	3,028	3,028
MRN-9	2,880	2,880
MRN-10	8,202	8,202
MRN-11	1,247	1,247
MRN-12	3,201	3,201
MRN-13	1,980	1,980

NOTE: The disturbed acreage for MRN-8 through MRN-13 is equated to the total mine acreage due to lack of data. Total disturbed acreage per mine areas of interest (MRN-8 through MRN-10) equals 14,110. Total disturbed acreage for the existing leases without mine proposals (MRN-11 through MRN-13) equals 6,428.

Therefore, the emission rates for the mining areas of interest (denoted by MRN-8 through MRN-10 in Table R8-1) and the existing leases without mine proposals (denoted by MRN-11 through MRN-13 in Table R8-1) are calculated to be 387.5 and 294.5 tons per year, respectively. The total emissions for each individual mine type were then distributed as a function of the fraction of total disturbed acreage as shown in Table R8-2. The method for determining emission rates for the aforementioned six mines is not as sophisticated as the technique described in Chapter 4 due to the lack of sufficient data.

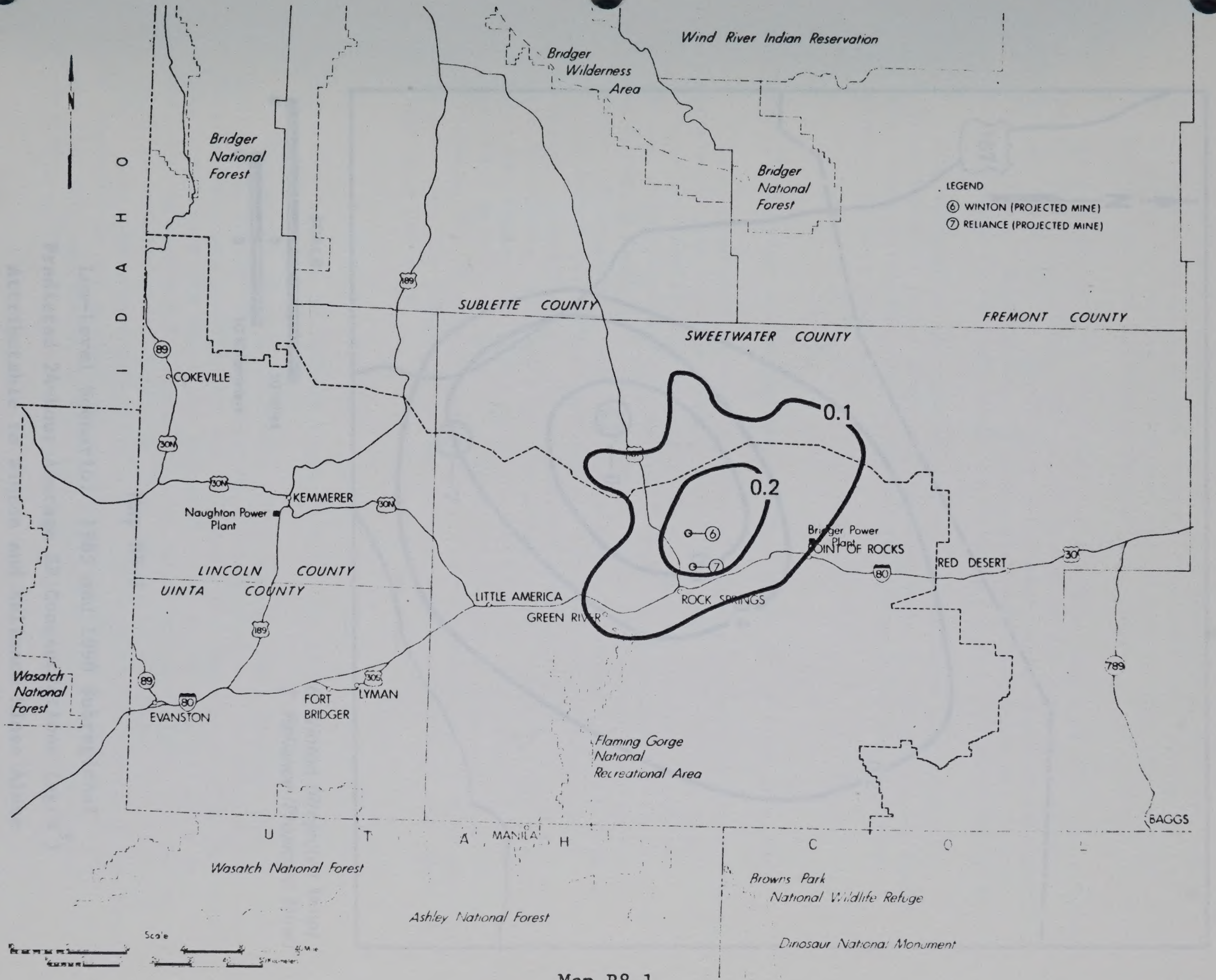
The Rock Springs meteorological data were used for all mines located in Sweetwater County; Fort Bridger meteorological data were used for all mines located within Lincoln and Uinta Counties. Prior to evaluation of the predicted impacts attributable to the low and high levels of mining development, the reader is reminded of the uncertainties inherent in the state-of-the-art fugitive dust emission and model prediction methods discussed in Chapter 4.

Low-Level Scenario

Model Predictions of Annual Average Impact on Suspended Particulate (SP) Concentrations

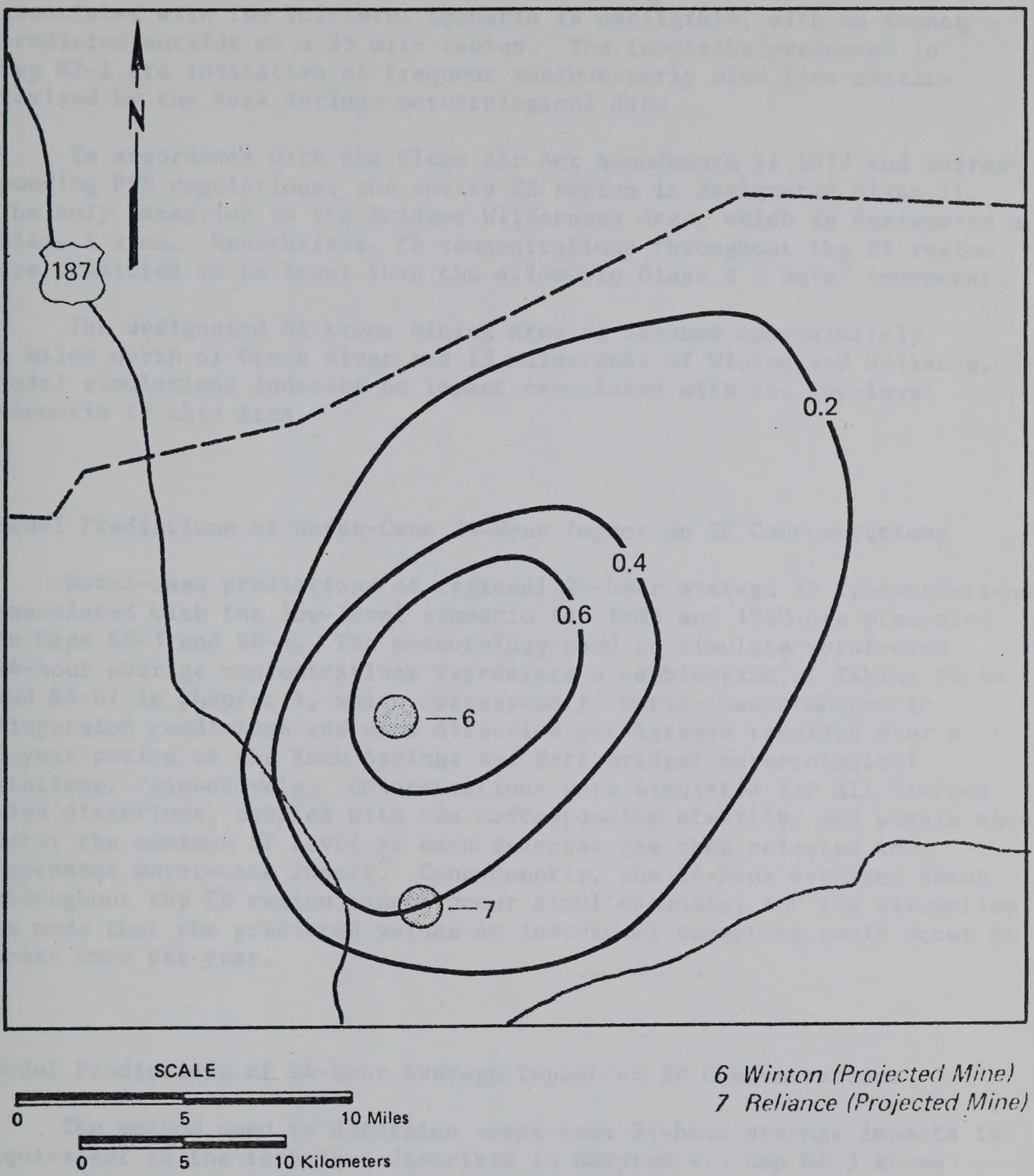
Map R8-1 depicts the regional distribution of simulated annual average SP concentrations in 1985 and 1990 from mining operations alone within the low-level scenario. The two mining areas of interest (Winton and Reliance) constituting the low-level scenario will not be operational in 1980, and estimated fugitive dust emission rates for both mines are identical for 1985 and 1990.

The model results represent the proportional contribution of mining activity to the levels specified in the standards. The model predictions are evaluated in accordance with PSD regulations since these apply to source-specific impact alone. An evaluation of the total (background plus mining) ambient levels of SP is presented later in the "Cumulative Air Quality Impacts" section of this report. A detailed presentation of simulated SP concentrations in the vicinity of the Winton and Reliance mines is shown in Map R8-2. The highest predicted SP levels are less than 1 $\mu g/m^3$ and occur within a 6 mile radius of Winton. The Winton mine contributes approximately 92% to peak simulated levels of 0.6 $\mu g/m^3$; Reliance accounts for the remaining 8%. In general, dispersion of emissions from the Winton mine dominates predicted concentrations in this subregion since emissions from Winton are estimated to be more than 2.5 times greater than the emissions from Reliance. However, the Reliance mine does have a significant impact (greater than 50%) on receptors located within 3 miles of Reliance. Regionally, the impact


Wind River Indian Reservation
Bridger Wilderness Area
Bridger National Forest
Bridger National Forest
IDAHO
LEGEND
⑥ WINTON (PROJECTED MINE)
⑦ RELIANCE (PROJECTED MINE)
SUBLETTE COUNTY
FREMONT COUNTY
SWEETWATER COUNTY
0.1
0.2
COKEVILLE
89
30N
KEMMERER
Naughton Power Plant
189
LINCOLN COUNTY
UINTA COUNTY
LITTLE AMERICA
GREEN RIVER
ROCK SPRINGS
Bridger Power Plant
POINT OF ROCKS
RED DESERT
80
30
789
Wasatch National Forest
EVANSTON
FORT BRIDGER
LYMAN
Flaming Gorge National Recreational Area
BAGGS
UTAH
MANILA
COLO
Wasatch National Forest
Ashley National Forest
Browns Park National Wildlife Refuge
Dinosaur National Monument
Scale

Map R8-1

Low-Level Scenario: 1985 and 1990 Predicted Annual Average SP Concentrations ($\mu g/m^3$) Attributable to Winton and Reliance Mines Alone


N
187
0.2
0.4
0.6
6
7
SCALE
0 5 10 Miles
0 5 10 Kilometers
6 Winton (Projected Mine)
7 Reliance (Projected Mine)

Map R8-2

Low-Level Scenario: 1985 and 1990 Subregional

Predicted 24-Hour Average SP Concentrations (μg/m^3)

Attributable to Winton and Reliance Mines Alone

associated with the low-level scenario is negligible, with no impact predicted outside of a 25 mile radius. The isopleths presented in Map R8-1 are indicative of frequent southwesterly wind flow characterized by the Rock Springs meteorological data.

In accordance with the Clean Air Act Amendments of 1977 and corresponding PSD regulations, the entire ES region is designated Class II. The only exception is the Bridger Wilderness Area, which is designated a Class I area. Nonetheless, SP concentrations throughout the ES region are predicted to be lower than the allowable Class I 5 $\mu g/m^3$ increment.

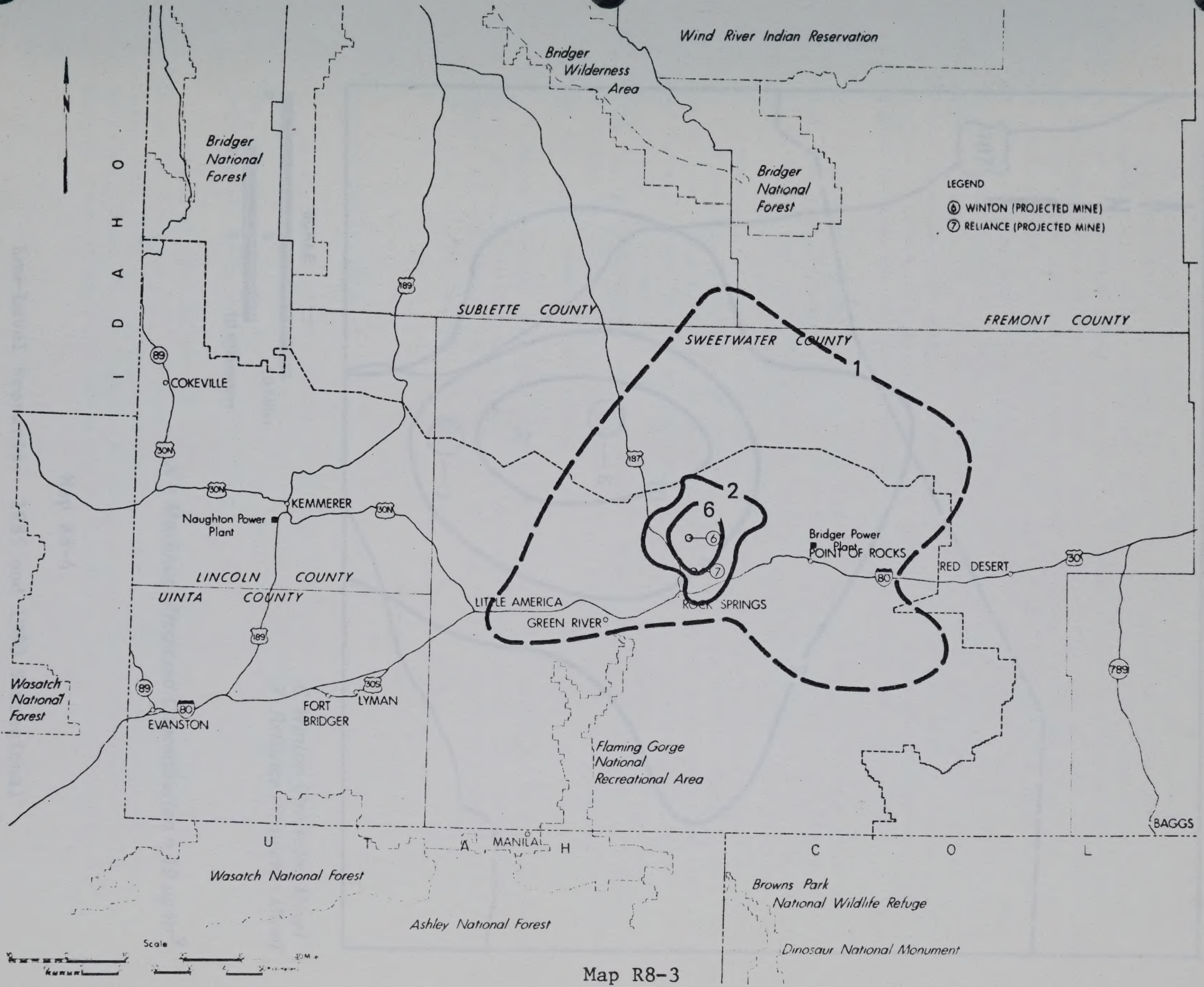
The designated NA trona mining area is located approximately 6 miles north of Green River and 13 miles west of Winton and Reliance. Model simulations indicate no impact associated with the low-level scenario in this area.

Model Predictions of Worst-Case 24-Hour Impact on SP Concentrations

Worst-case predictions of regional 24-hour average SP concentrations associated with the low-level scenario for 1985 and 1990 are presented in Maps R8-3 and R8-4. The meteorology used to simulate worst-case 24-hour average concentrations represents a combination of Tables R4-60 and R4-61 in Chapter 4, which correspond to worst-case atmospheric dispersion conditions and wind direction persistence recorded over a 5-year period at the Rock Springs and Fort Bridger meteorological stations, respectively. Concentrations were simulated for all sixteen wind directions, coupled with the corresponding stability and persistence data; the maximum SP level at each receptor was then selected to represent worst-case impact. Consequently, the 24-hour averages shown throughout the ES region cannot occur simultaneously, but the assumption is made that the predicted values at individual receptors could occur at least once per year.

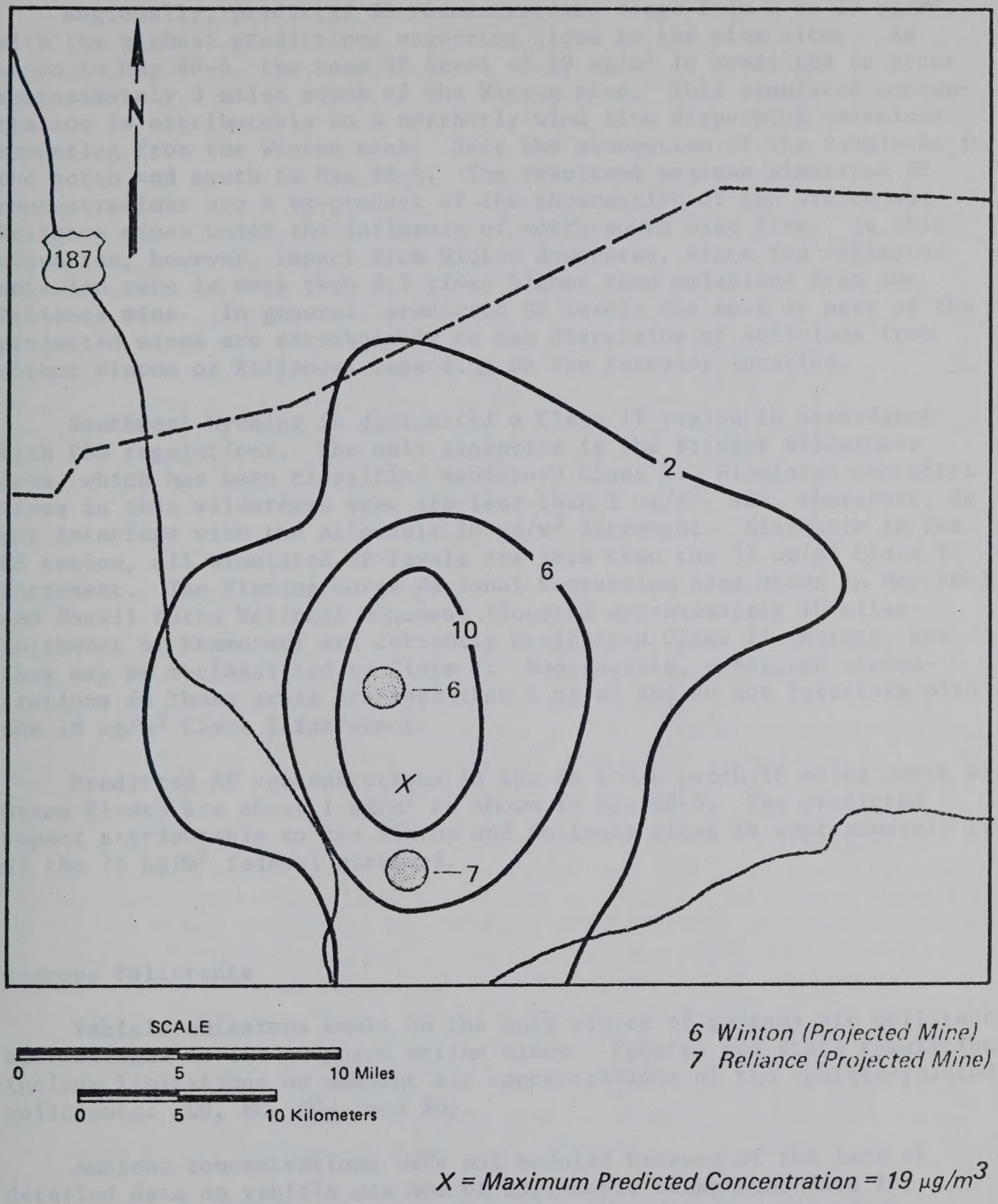
Model Predictions of 24-Hour Average Impact on SP Concentrations

The method used to determine worst-case 24-hour average impacts is equivalent to the technique described in Chapter 4. Map R8-3 shows these worst-case predictions for 1985 and 1990 associated with the mines that constitute the low-level scenario. The mines considered in this analysis (Winton and Reliance) are not operational in 1980, and estimated fugutive dust emission rates for both mines are identical for 1985 and 1990. Note that the concentration pattern depicted in Map R8-3 represents a composite of the maximum model predictions for all wind directions, and that the assumption is made that predicted levels at individual receptors could occur at least once per year.


Wind River Indian Reservation
Bridger Wilderness Area
Bridger National Forest
Bridger National Forest
N
I D A H O
LEGEND
⑥ WINTON (PROJECTED MINE)
⑦ RELIANCE (PROJECTED MINE)
SUBLETTE COUNTY
FREMONT COUNTY
SWEETWATER COUNTY
1
2
6
COKEVILLE
89
189
30N
187
KEMMERER
Naughton Power Plant
Bridger Power Plant
POINT OF ROCKS
RED DESERT
30
80
LINCOLN COUNTY
UINTA COUNTY
LITTLE AMERICA
GREEN RIVER
ROCK SPRINGS
Wasatch National Forest
EVANSTON
FORT BRIDGER
LYMAN
30S
Flaming Gorge National Recreational Area
789
BAGGS
U T A H
MANILA
C O L
Wasatch National Forest
Ashley National Forest
Browns Park National Wildlife Refuge
Dinosaur National Monument
Scale

Map R8-3

Low-Level Scenario: 1985 and 1990 Predicted 24-Hour Average SP Concentrations ($\mu g/m^3$)
Attributable to Winton and Reliance Mines Alone


187
N
2
6
10
6
X
7
SCALE
0
5
10 Miles
0
5
10 Kilometers
6 Winton (Projected Mine)
7 Reliance (Projected Mine)
X = Maximum Predicted Concentration = 19 μg/m3

Map R8-4

Low-Level Scenario: 1985 and 1990 Subregional Predicted 24-Hour Average SP Concentrations ($\mu g/m^3$) Attributable to Winton and Reliance Mines Alone

801142
803263

Regionally, predicted SP concentrations range from 0 to 19 $\mu g/m^3$, with the highest predictions occurring close to the mine sites. As shown in Map R8-4, the peak SP level of 19 $\mu g/m^3$ is predicted to occur approximately 3 miles south of the Winton mine. This simulated concentration is attributable to a northerly wind flow dispersing emissions emanating from the Winton mine. Note the elongation of the isopleths to the north and south in Map R8-4. The resultant maximum simulated SP concentrations are a by-product of the interaction of the Winton and Reliance mines under the influence of north-south wind flow. In this situation, however, impact from Winton dominates, since its estimated emission rate is more than 2.5 times higher than emissions from the Reliance mine. In general, predicted SP levels due east or west of the projected mines are attributable to the dispersion of emissions from either Winton or Reliance, depending on the receptor location.

Southwest Wyoming is designated a Class II region in accordance with PSD regulations. The only exception is the Bridger Wilderness Area, which has been classified mandatory Class I. Simulated concentrations in this wilderness area are less than 1 $\mu g/m^3$, and, therefore, do not interfere with the allowable 10 $\mu g/m^3$ increment. Elsewhere in the ES region, all simulated SP levels are less than the 37 $\mu g/m^3$ Class II increment. The Flaming Gorge National Recreation Area shown in Map R8-3 and Fossil Butte National Monument (located approximately 10 miles northwest of Kemmerer) are currently designated Class II regions, but they may be reclassified to Class I. Nonetheless, predicted concentrations in these areas are less than 1 $\mu g/m^3$ and do not interfere with the 10 $\mu g/m^3$ Class I increment.

Predicted SP concentrations in the NA trona patch (6 miles north of Green River) are about 1 $\mu g/m^3$ as shown in Map R8-3. The predicted impact attributable to the Winton and Reliance mines is approximately 1% of the 75 $\mu g/m^3$ federal standard.

Gaseous Pollutants

Vehicle emissions would be the only source of gaseous air pollutants attributable to the proposed action mines. Federal and state regulations include limitations on ambient air concentrations of the vehicle-related pollutants: CO, HC, NO_2, and SO_2.

Ambient concentrations were not modeled because of the lack of detailed data on vehicle use and of applicable background data for these pollutants. However, recent studies (U.S. Department of the Interior 1976) of the impact of vehicle emissions associated with western coal mines were reviewed to estimate the probable range of

impact. In these studies, concentrations of the above pollutants for similar mining operations had either been modeled or estimated from standard approximation techniques. In all cases, the levels of maximum pollutant concentrations from vehicle emissions were insignificant when compared to standards.

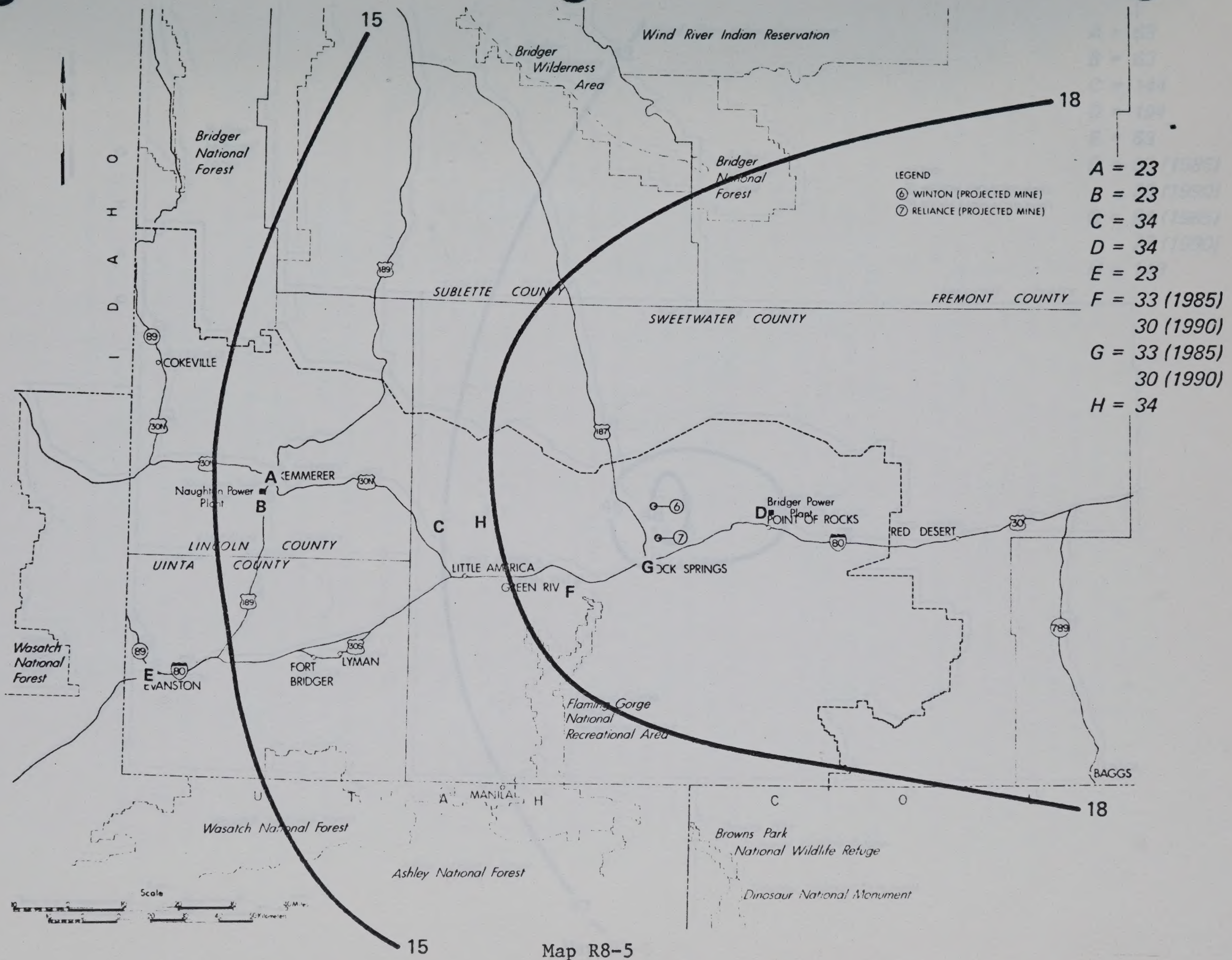
Maximum predicted concentrations of CO ranged between 0.02 and 0.44% of the 1-hour 40,000 $\mu g/m^3$ standard. Maximum predicted HC concentrations ranged between 0.88 and 3.44% of the 3-hour 160 $\mu g/m^3$ standard. Maximum predicted NO_2 concentrations ranged between 0.60 and 3.0% of the standards, while maximum predicted concentrations of SO_2 ranged between 0.02 and 0.33% of the standards. Air quality standards for SO_2 and NO_x are shown in Table R4-64. The values represent predictions at less than one-half mile from the mines. Predictions were significantly less at distances further from the mines. Assuming similar vehicle activity for all western coal mines, the regional cumulative impact of vehicle emissions on ambient concentrations of gaseous pollutants would be minimal and insignificant compared to their respective standards.

Cumulative Impacts on Air Quality

The cumulative TSP impacts presented in this section have been computed by adding predicted mine-related SP concentrations to projected background concentrations. In this study, background refers to the resultant SP concentrations attributable to the combined impacts of all sources in the ES region other than the mines that were modeled. Total SP levels (mine plus background) characterize predicted ambient air quality, and total concentrations may be compared to federal and Wyoming ambient air quality standards. Background-related SP concentrations to be added to the mine simulations for each analysis year are presented in Table R8-2. Note that these levels are categorized as rural, industrial, or urban background within each county in the ES region. Similar to Chapter 4, the mid-points of the background ranges were graphically combined with mine impact simulations for a pictorial representation of cumulative impacts. Use of these background range mid-points is purely arbitrary and applied for illustrative purposes only. These simulated annual and 24-hour average cumulative TSP impacts are presented in Maps R8-5 and R8-6, respectively. Each of the cumulative impact maps depict isolated points of maximum predicted impact. These "hot spots" are denoted by letters A through H on the maps.

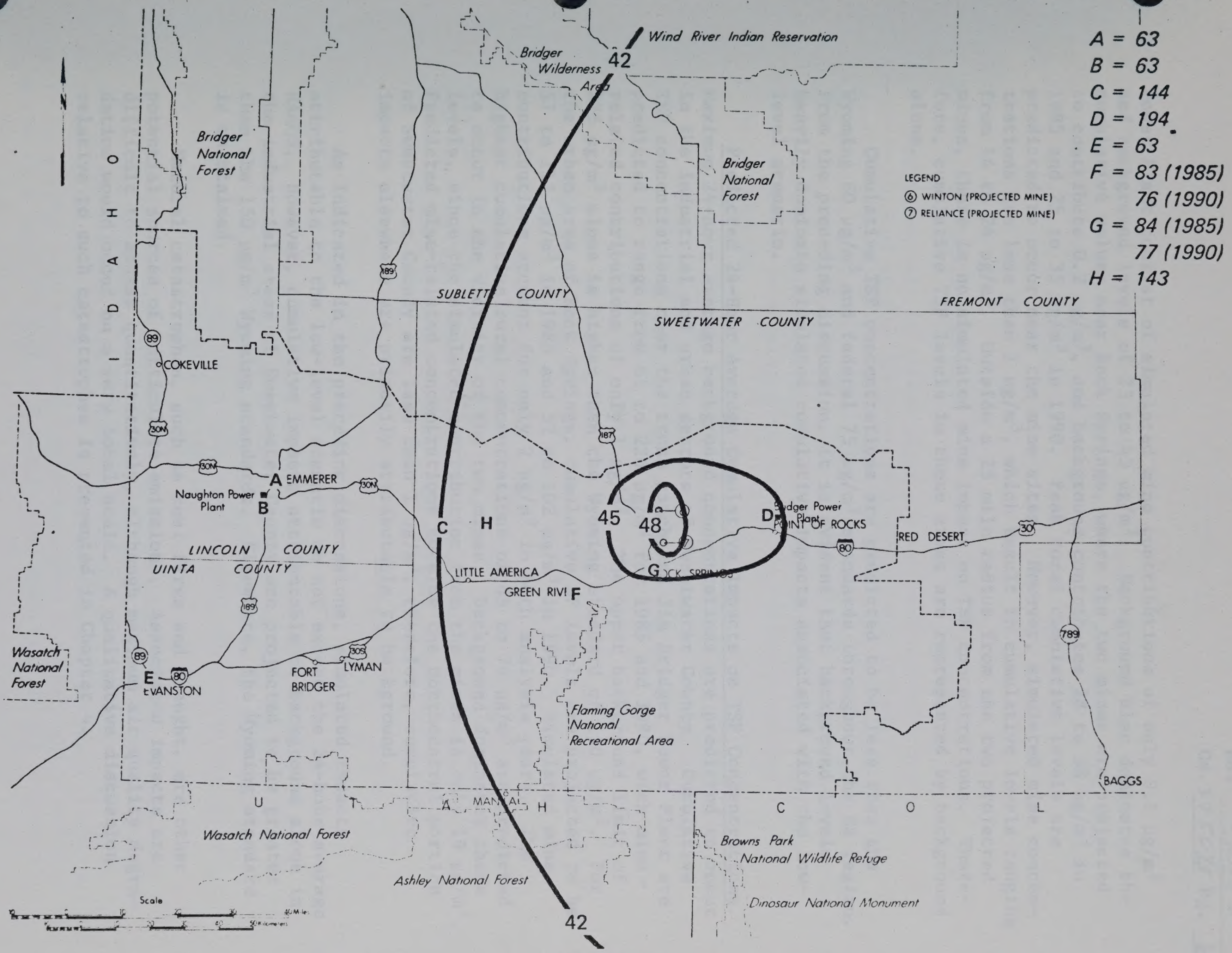
Predicted Annual Average Cumulative Impacts on TSP Concentrations. The highest background concentrations for 1985 and 1990 are projected to be in the industrial and urban sectors of Sweetwater County. Cumulative TSP levels in the vicinities of the trona patch and Jim Bridger

803260
803340


15
18
A = 23
B = 23
C = 34
D = 34
E = 23
F = 33 (1985)
30 (1990)
G = 33 (1985)
30 (1990)
H = 34
N
IDAHO
Wind River Indian Reservation
Bridger Wilderness Area
Bridger National Forest
LEGEND
⑥ WINTON (PROJECTED MINE)
⑦ RELIANCE (PROJECTED MINE)
SUBLETTE COUNTY
FREMONT COUNTY
SWEETWATER COUNTY
LINCOLN COUNTY
UINTA COUNTY
COKEVILLE
KEMMERER
Naughton Power Plant
LITTLE AMERICA
GREEN RIV
ROCK SPRINGS
Bridger Power Plant
POINT OF ROCKS
RED DESERT
Wasatch National Forest
EVANSTON
FORT BRIDGER
LYMAN
Flaming Gorge National Recreational Area
BAGGS
UTAH
MANILA
COLO
Browns Park National Wildlife Refuge
Dinosaur National Monument
Ashley National Forest
Scale
189
89
30N
80
187
30
789
30S

Map R8-5

Low-Level Scenario: 1985 and 1990 Cumulative Predicted Annual Average TSP Concentrations ($\mu g/m^3$)


A = 63
B = 63
C = 144
D = 194
E = 63
F = 83 (1985)
76 (1990)
G = 84 (1985)
77 (1990)
H = 143
Wind River Indian Reservation
Bridger Wilderness Area
42
Bridger National Forest
Bridger National Forest
LEGEND
⑥ WINTON (PROJECTED MINE)
⑦ RELIANCE (PROJECTED MINE)
N
IDAHO
SUBLETTE COUNTY
FREMONT COUNTY
SWEETWATER COUNTY
COKEVILLE
KEMMERER
Naughton Power Plant
LINCOLN COUNTY
UINTA COUNTY
C
H
45
48
Bridger Power Plant
D
POINT OF ROCKS
RED DESERT
LITTLE AMERICA
G
ROCK SPRINGS
GREEN RIVER
F
Wasatch National Forest
E
EVANSTON
FORT BRIDGER
LYMAN
Flaming Gorge National Recreational Area
BAGGS
UTAH
COLO
MANILA
Wasatch National Forest
Ashley National Forest
Browns Park National Wildlife Refuge
Dinosaur National Monument
Scale
40 Miles
50 Kilometers
42
89
30N
189
187
80
30
789
30S

Map R8-6

Low-Level Scenario: 1985 and 1990 Cumulative Predicted 24-Hour Average TSP Concentrations (μg/m^3)

Power Plant consist of simulated mine contributions of only 0.1 μg/m^3 and background levels of 23 to 45 μg/m^3. Background also dominates the cumulative values near Rock Springs, where the two mines are projected to contribute 0.2 μg/m^3, and background contributes 28 to 38 μg/m^3 in 1985 and 25 to 35 μg/m^3 in 1990. Peak rural cumulative levels are predicted to occur near the mine sites. However, simulated mine concentrations are less than 1 μg/m^3, which result in cumulative levels ranging from 14 to 24 μg/m^3. Outside a 25 mile radius from the two projected mines, there is no simulated mine impact on TSP concentrations. Therefore, cumulative TSP levels in these areas are represented by background alone.

Cumulative TSP concentrations are predicted to be less than the Wyoming 60 μg/m^3 and federal 75 μg/m^3 standards throughout the ES region. From the preceding discussion, it is evident that background levels heavily dominate simulated cumulative impacts associated with the low-level scenario.

Predicted 24-Hour Average Cumulative Impacts on TSP Concentrations. Maximum 24-hour average background concentrations are predicted to occur in the industrial and urban sectors of Sweetwater County. Cumulative TSP concentrations near the trona patch and Jim Bridger Power Plant are predicted to range from 61 to 226 μg/m^3 for 1985 and 1990, with mine-related contributions of only 1 μg/m^3. The upper background limit of 225 μg/m^3 alone is higher than the Wyoming standard of 150 μg/m^3. For the urban area of Rock Springs, cumulative SP levels are projected to be 57 to 112 μg/m^3 in 1985 and 52 to 102 μg/m^3 in 1990. Simulated mine contributions account for only 2 μg/m^3 in both analysis years. The highest cumulative rural concentrations of 49 to 74 μg/m^3 are predicted to occur in the vicinity of the two mines. Background dominates these levels, since the simulated contribution from the mines is only 19 μg/m^3. Predicted mine-related concentrations outside the northcentral portion of Sweetwater County are less than 1 μg/m^3; therefore, cumulative impacts elsewhere are primarily attributable to background.

As indicated in the preceding discussions, simulated impacts attributable to the low-level scenario do not exceed the 24-hour average NAAQS. However, cumulative impacts attributable to background alone in the industrial areas of Sweetwater County are projected to be greater than the 150 μg/m^3 Wyoming standards. Elsewhere, the Wyoming standard is maintained.

Natural catastrophes, such as coal fires and drought, are other potential sources of particulate emissions. Associated impacts are difficult to assess quantitatively, although maximum air quality degradation would occur on a very local scale. A qualitative discussion relative to such catastrophes is presented in Chapter 4.

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Sec. BG
Ent 7/3/78
Cd. 12502 Ps. b

Power Plant consist of simulated mine contributions of only 0.1 μg/m^3 and background levels of 23 to 45 μg/m^3. Background also dominates the cumulative values near Rock Springs, where the two mines are projected to contribute 0.2 μg/m^3, and background contributes 28 to 38 μg/m^3 in 1985 and 23 to 33 μg/m^3 in 1990. Peak rural cumulative levels are predicted to occur near the mine sites. However, simulated mine concentrations are less than 1 μg/m^3, which result in cumulative levels ranging from 14 to 24 μg/m^3. Outside a 25 mile radius from the two projected mines, there is no simulated mine impact on TSP concentrations. Therefore, cumulative TSP levels in these areas are represented by background alone.

Cumulative TSP concentrations are predicted to be less than the Wyoming 60 μg/m^3 and federal 75 μg/m^3 standards throughout the ES region. From the preceding discussion, it is evident that background levels heavily dominate simulated cumulative impacts associated with the low-level scenario.

Predicted 24-hour Average Cumulative Impacts on TSP Concentrations. Maximum 24-hour average background concentrations are predicted to occur in the industrial and urban sectors of Sweetwater County. Cumulative TSP concentrations near the trona patch and Jim Bridger Power Plant are predicted to range from 81 to 226 μg/m^3 for 1985 and 1990, with mine-related contributions of only 1 μg/m^3. The upper background limit of 225 μg/m^3 alone is higher than the Wyoming standard of 150 μg/m^3. For the urban area of Rock Springs, cumulative TP levels are projected to be 57 to 112 μg/m^3 in 1985 and 52 to 102 μg/m^3 in 1990. Simulated mine contributions account for only 2 μg/m^3 in both analysis years. The highest cumulative rural concentrations of 49 to 76 μg/m^3 are predicted to occur in the vicinity of the two mines. Background dominates these levels, since the simulated contribution from the mines is only 19 μg/m^3. Predicted mine-related concentrations outside the northcentral portion of Sweetwater County are less than 1 μg/m^3; therefore, cumulative impacts elsewhere are primarily attributable to background.

As indicated in the preceding discussions, simulated impacts attributable to the low-level scenario do not exceed the 24-hour average NAAQS. However, cumulative impacts attributable to background alone in the industrial areas of Sweetwater County are projected to be greater than the 150 μg/m^3 Wyoming standards. Elsewhere, the Wyoming standard is maintained.

Natural catastrophes, such as coal fires and drought, are other potential sources of particulate emissions. Associated impacts are difficult to assess quantitatively, although maximum air quality degradation would occur on a very local scale. A qualitative discussion relative to such catastrophes is presented in Chapter 4.

Cumulative impacts on gaseous pollutants (CO, HC, NO_2, and SO_2) are similar to those associated with the proposed actions and, therefore, insignificant when compared to the standards. Refer to Chapter 4 for a more detailed discussion.

Indirect Air Quality Impacts

Additional air pollutant emissions would result from indirect sources related to the low-level coal development scenario. Consequently, baseline SP concentrations are also expected to increase and have been projected to future analysis years; these projected levels are equivalent to the ranges presented in Table R8-2. The SP concentrations simulated for Winton and Reliance have been combined with projected baseline levels to determine the cumulative impacts discussed in the previous sections.

Quantitative indirect source impacts on variations in baseline SO_2 and NO_x concentrations are unknown (see Chapter 2). However, the contributions from the mines are expected to be negligible.

Probable Cumulative Impacts

A brief enumeration on the transport of aerosols and their possible effects on climate is presented in the Chapter 2. However, the available data do not provide a firm basis for conclusive statements about what role low-level coal development activities would play in altering the ES region's existing climate over the next 15 years.

Visibility

The method used to evaluate the impact of the low-level scenario on visibility is identical to the technique described in Chapter 4. Regional background visibilities are assumed to be 40 miles for each year, based on current visibility observations and evaluation of projected regional background SP values.

For the low-level scenario, the worst-case, 24-hour SP concentrations attain values as high as 19 $\mu g/m^3$ in the vicinity of the projected Winton and Reliance mines. This corresponds to a visibility of 37.8 miles, assuming a background of 40 miles. Most of the region, however, is associated with simulated levels less than 10 $\mu g/m^3$, which corresponds to a visibility of 38.8 miles, or a reduction of 1.2 miles from

the background. Concentrations in the Bridger Wilderness Area (Class I) and in the Flaming Gorge Recreational Area (Class II) are less than 0.3 μg/m^3, and impact on visibility degradation is negligible.

High-Level Scenario

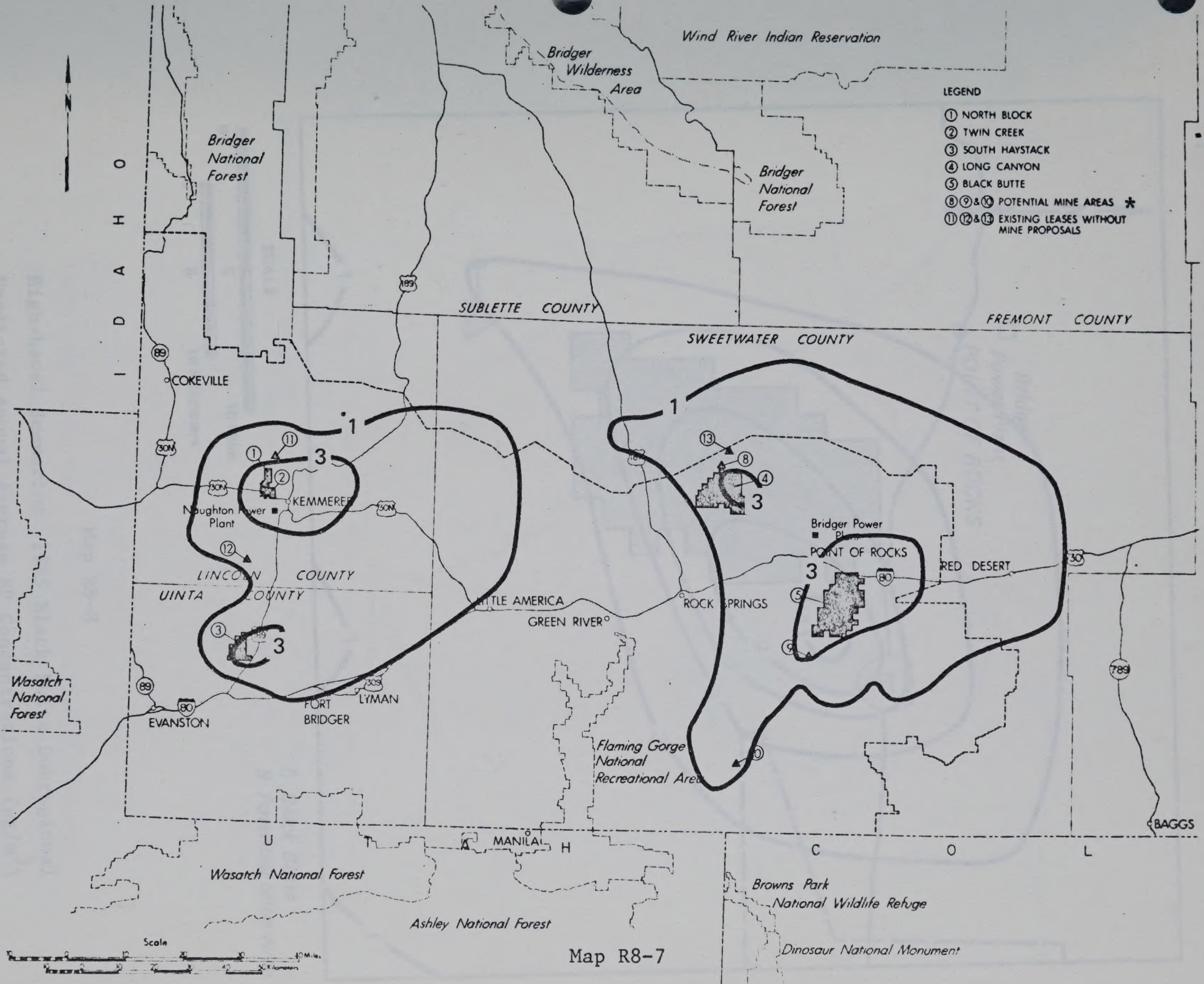
Model Predictions of Annual Average Impact on SP Concentrations for 1985 and 1990

Maps R8-7 through R8-18 present the cumulative regional and subregional distributions of annual average SP concentrations for 1985 and 1990 from the mining operations alone. As discussed earlier, 1980 impacts are equivalent to those presented in Chapter 4. The mines considered in this chapter include the five proposed action mines, the three existing leases without proposed mine plans (MRN-11 through MRN-13), and the three mining areas of interest (MRN-8 through MRN-10). Except for Black Butte and Twin Creek, the particulate emission rates for each proposed and projected mine varies insignificantly from 1985 to 1990; therefore, the maps depicting SP impacts for both analysis years are very similar. Consequently, a discussion of the model predictions for annual average SP concentrations applies to both years.

Regionally, predicted SP levels attributable to the mining operations vary from 1 to 11 μg/m^3 in 1985 and 1 to 9 μg/m^3 in 1990. Since the sum of estimated particulate emission rates from all mines in the ES region is highest in 1985, it follows that 1985 predicted impacts are also greatest. The highest concentrations occur close to the actual mine sites, and the isopleths depicting such levels are skewed to the east and northeast. This type of distribution is attributable to the predominant frequency of west and southwesterly winds as recorded at the Fort Bridger and Rock Springs meteorological stations. The highest concentrations of approximately 11 μg/m^3 in 1985 and 9 μg/m^3 in 1990 are predicted to occur within approximately 3 miles northeast of the Black Butte mine as shown by Maps R8-8 and R8-14. Concentrations resulting from emissions at the Black Butte mine alone constitute more than 95% of these maximum SP levels. Contributions from the Black Butte mine to predicted levels of 3 to 11 μg/m^3 in 1985 and 3 to 9 μg/m^3 in 1990 range from 85 to 95% for both analysis years. Black Butte's highest contributions occur in the vicinity of the mine and decrease with distance away from the mine.

The second highest subregional concentrations of 5 to 7 μg/m^3 are predicted to occur about the North Block and Twin Creek mines. Maps R8-10 and R8-16 depict maximum predicted SP concentrations of 7 μg/m^3 for both

804092
80412

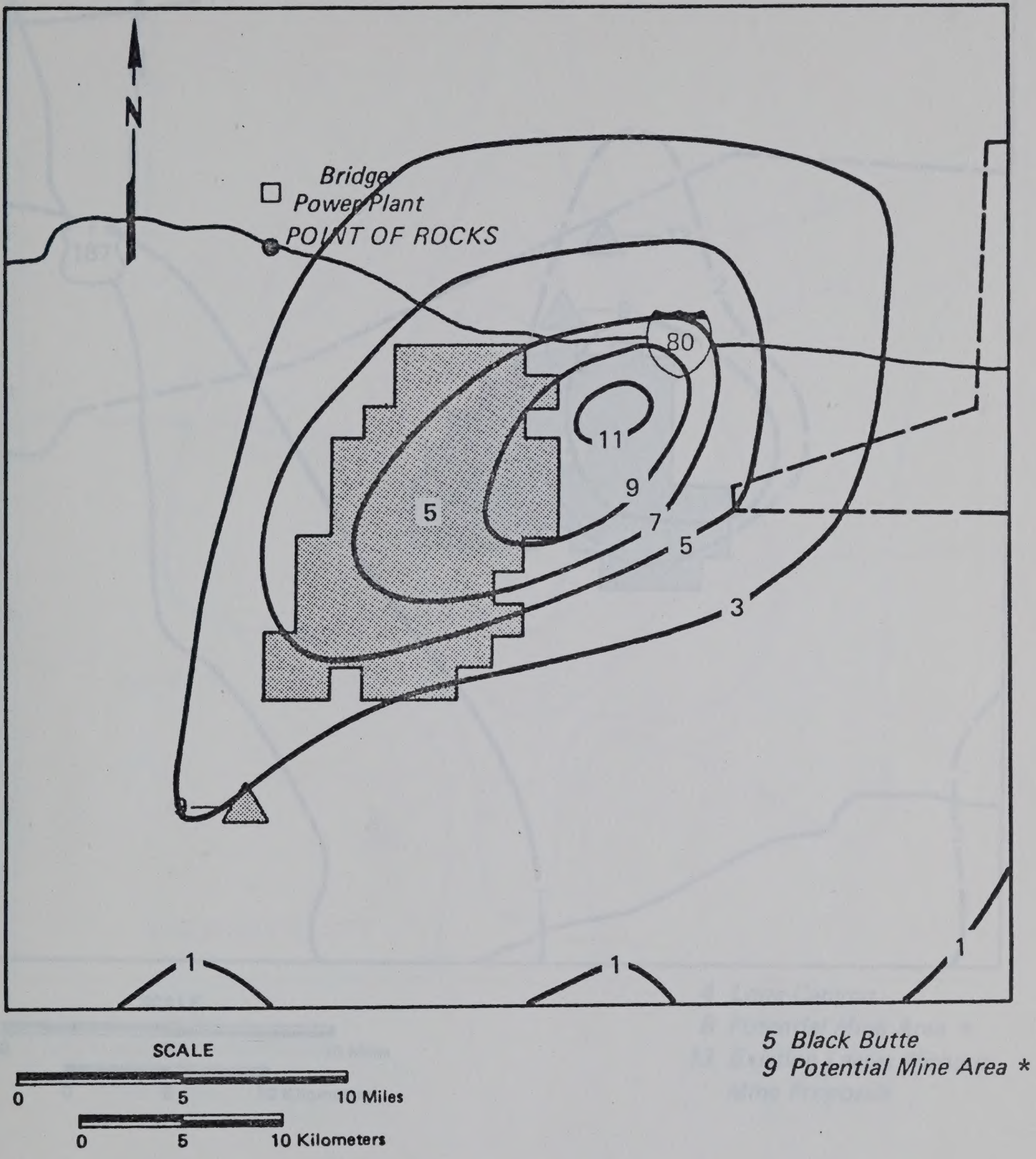

N
Wind River Indian Reservation
Bridger Wilderness Area
Bridger National Forest
Bridger National Forest
LEGEND
① NORTH BLOCK
② TWIN CREEK
③ SOUTH HAYSTACK
④ LONG CANYON
⑤ BLACK BUTTE
⑧⑨&⑩ POTENTIAL MINE AREAS *
⑪⑫&⑬ EXISTING LEASES WITHOUT MINE PROPOSALS
I D A H O
SUBLETTE COUNTY
FREMONT COUNTY
SWEETWATER COUNTY
LINCOLN COUNTY
UINTA COUNTY
COKEVILLE
KEMMERER
Naughton Power Plant
Bridger Power Plant
POINT OF ROCKS
RED DESERT
LITTLE AMERICA
GREEN RIVER
ROCK SPRINGS
EVANSTON
FORT BRIDGER
LYMAN
MANILA
BAGGS
Wasatch National Forest
Flaming Gorge National Recreational Area
U T A H
C O L
Wasatch National Forest
Ashley National Forest
Browns Park National Wildlife Refuge
Dinosaur National Monument
1
3
3
1
3
3
Scale
40 Miles
Kilometers

Map R8-7

High-Level Scenario: 1985 Predicted Annual Average SP Concentrations (μg/m^3)

Attributable to the Mines Alone

*Equivalent to "mine areas of interest."

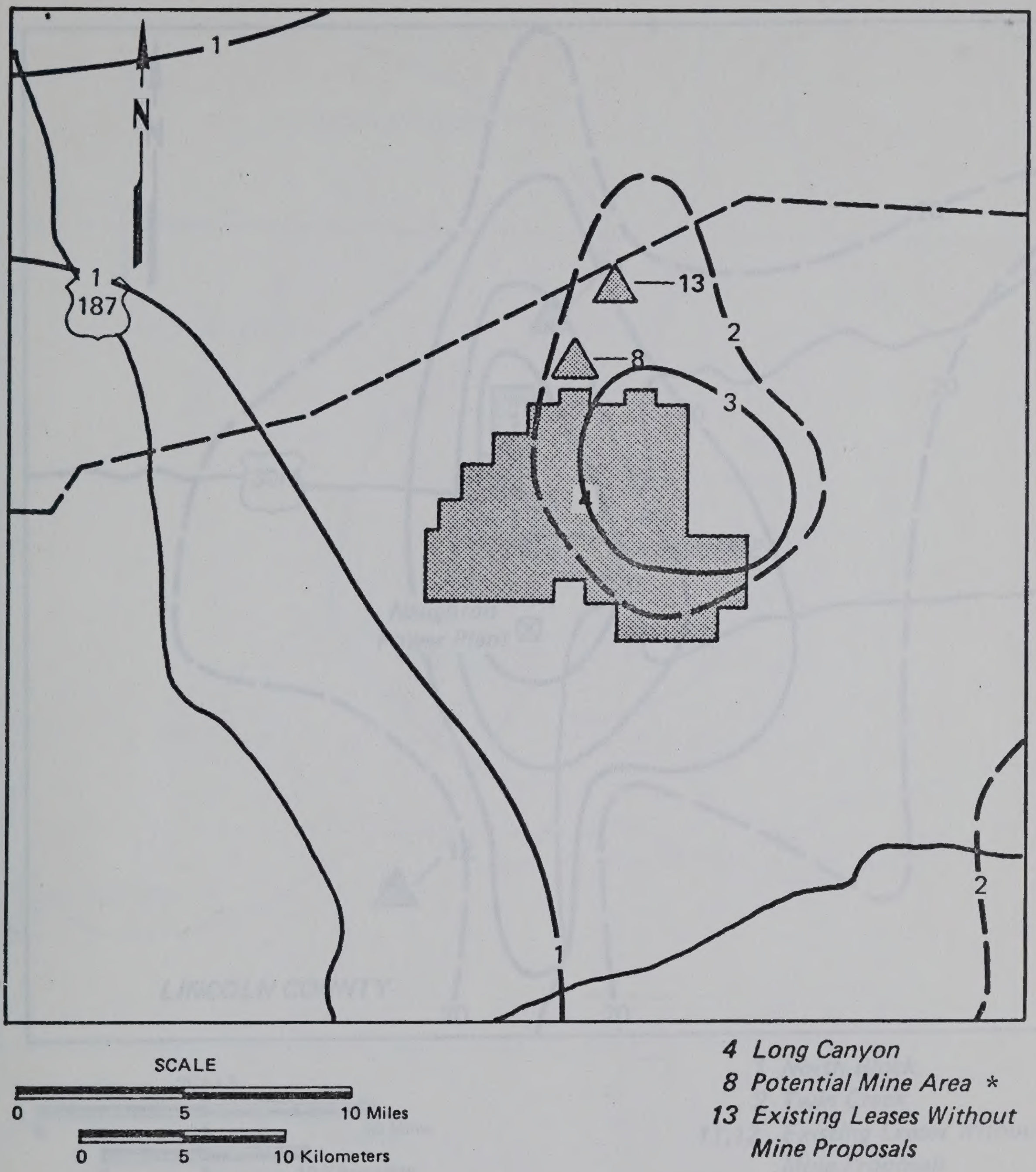

N
Bridger Power Plant
POINT OF ROCKS
80
11
9
7
5
3
5
1
1
1
SCALE
0 5 10 Miles
0 5 10 Kilometers
5 Black Butte
9 Potential Mine Area *

Map R8-8

High-Level Scenario: 1985 Black Butte Subregional
Predicted Annual Average SP Concentrations ($\mu g/m^3$)
Attributable to the Mines Alone

*Equivalent to "mine areas of interest."

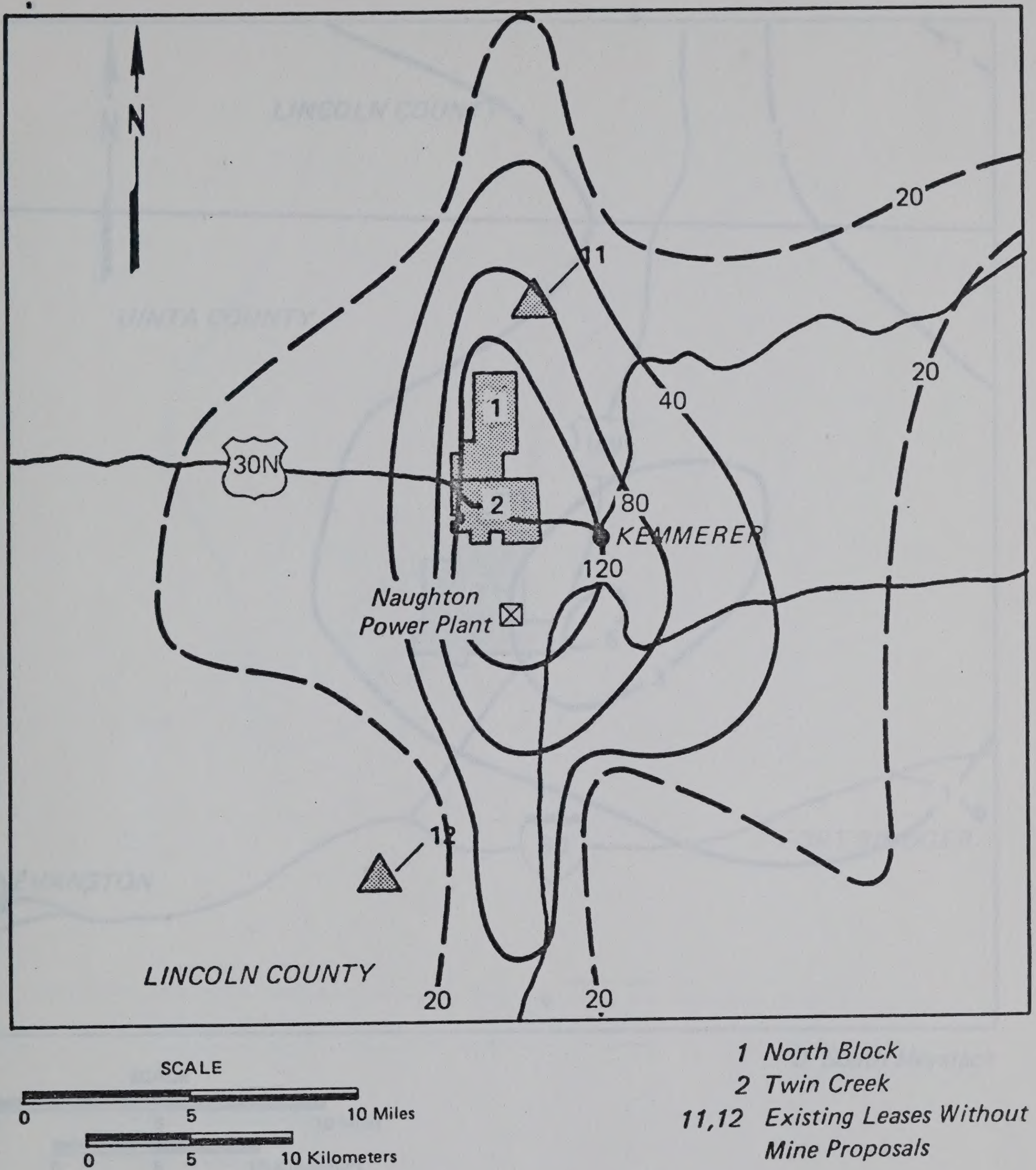
801144
804053


1
N
1
187
13
8
2
3
4
2
1
SCALE
0 5 10 Miles
0 5 10 Kilometers
4 Long Canyon
8 Potential Mine Area *
13 Existing Leases Without Mine Proposals

Map R8-9

High-Level Scenario: 1985 Long Canyon Subregional Predicted Annual Average SP Concentrations ($\mu g/m^3$) Attributable to the Mines Alone

*Equivalent to "mine areas of interest."


N
20
11
20
40
1
30N
2
80
KEMMERER
120
Naughton
Power Plant
12
LINCOLN COUNTY
20
20
SCALE
0
5
10 Miles
0
5
10 Kilometers

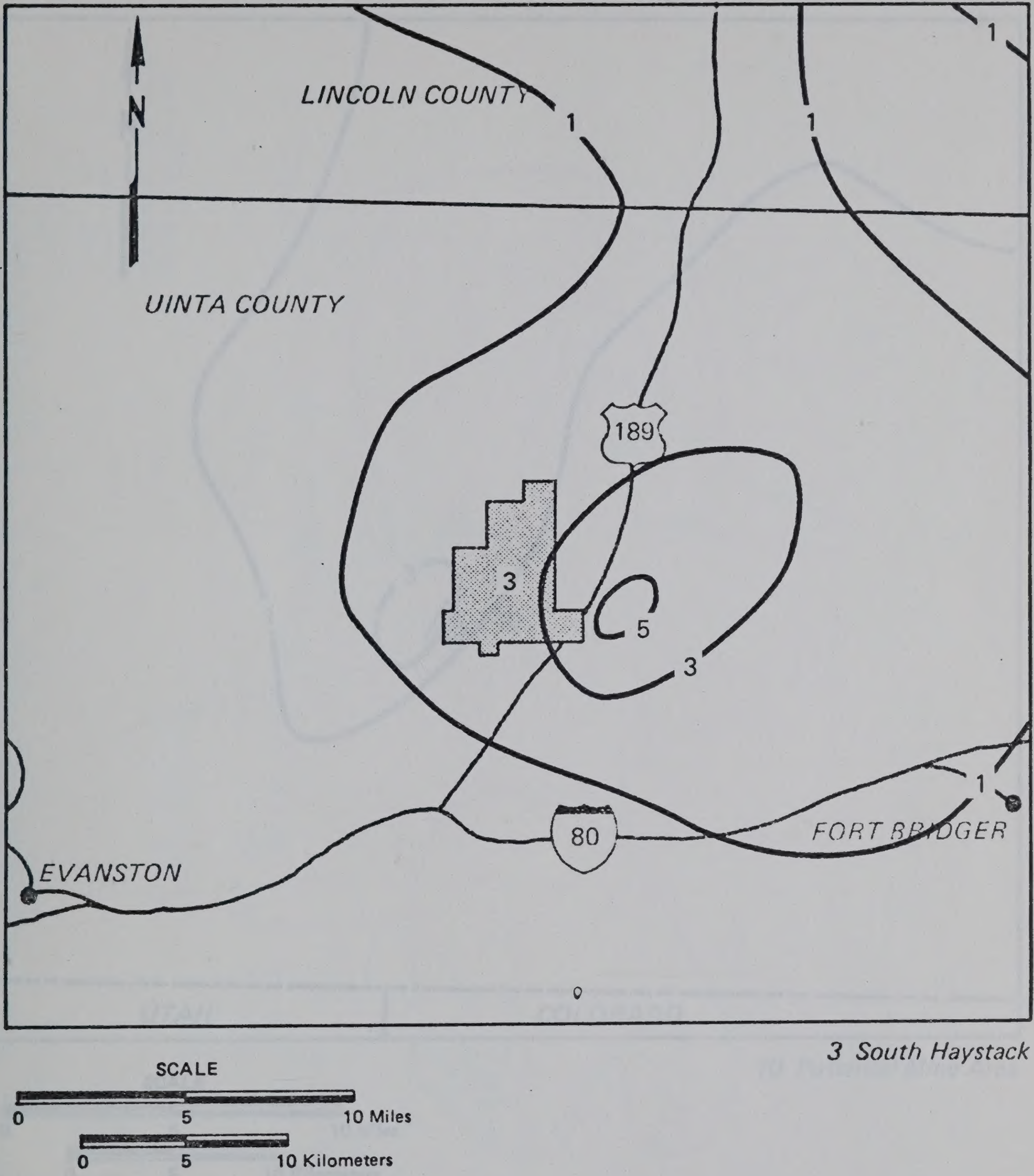
1 North Block
2 Twin Creek
11,12 Existing Leases Without Mine Proposals

X = Maximum Predicted Concentration = 264 μg/m^3

Map R8-10

High-Level Scenario: 1985 North Block-Twin Creek Subregional Predicted Annual Average SP Concentrations (μg/m^3) Attributable to the Mines Alone

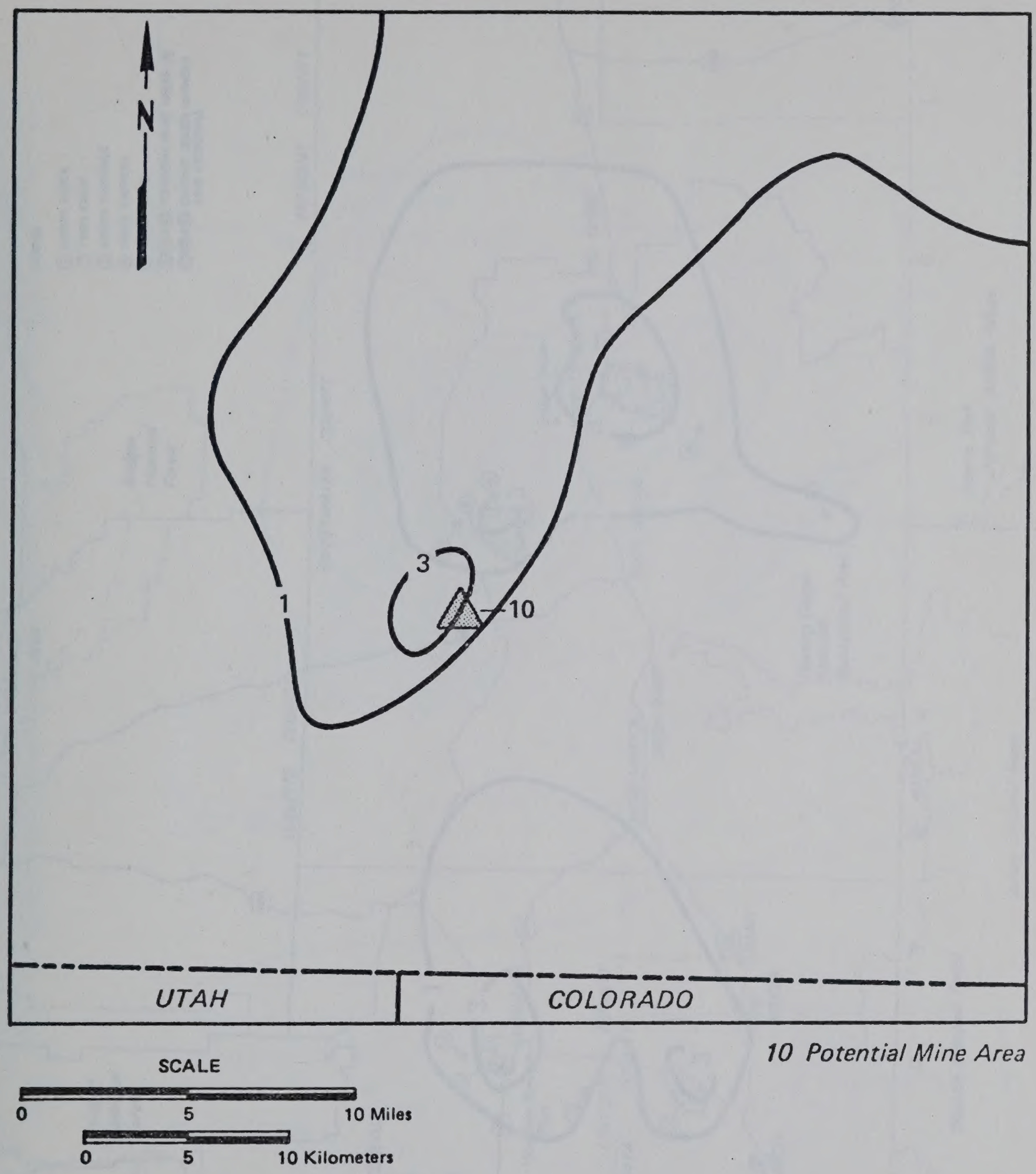
804093


N
LINCOLN COUNTY
UINTA COUNTY
1
1
1
1
189
3
5
3
80
EVANSTON
FORT BRIDGER
3 South Haystack
SCALE
0
5
10 Miles
0
5
10 Kilometers

Map R8-11

High-Level Scenario: 1985 South Haystack Subregional Predicted Annual Average SP Concentrations (μg/m^3) Attributable to the Mines Alone

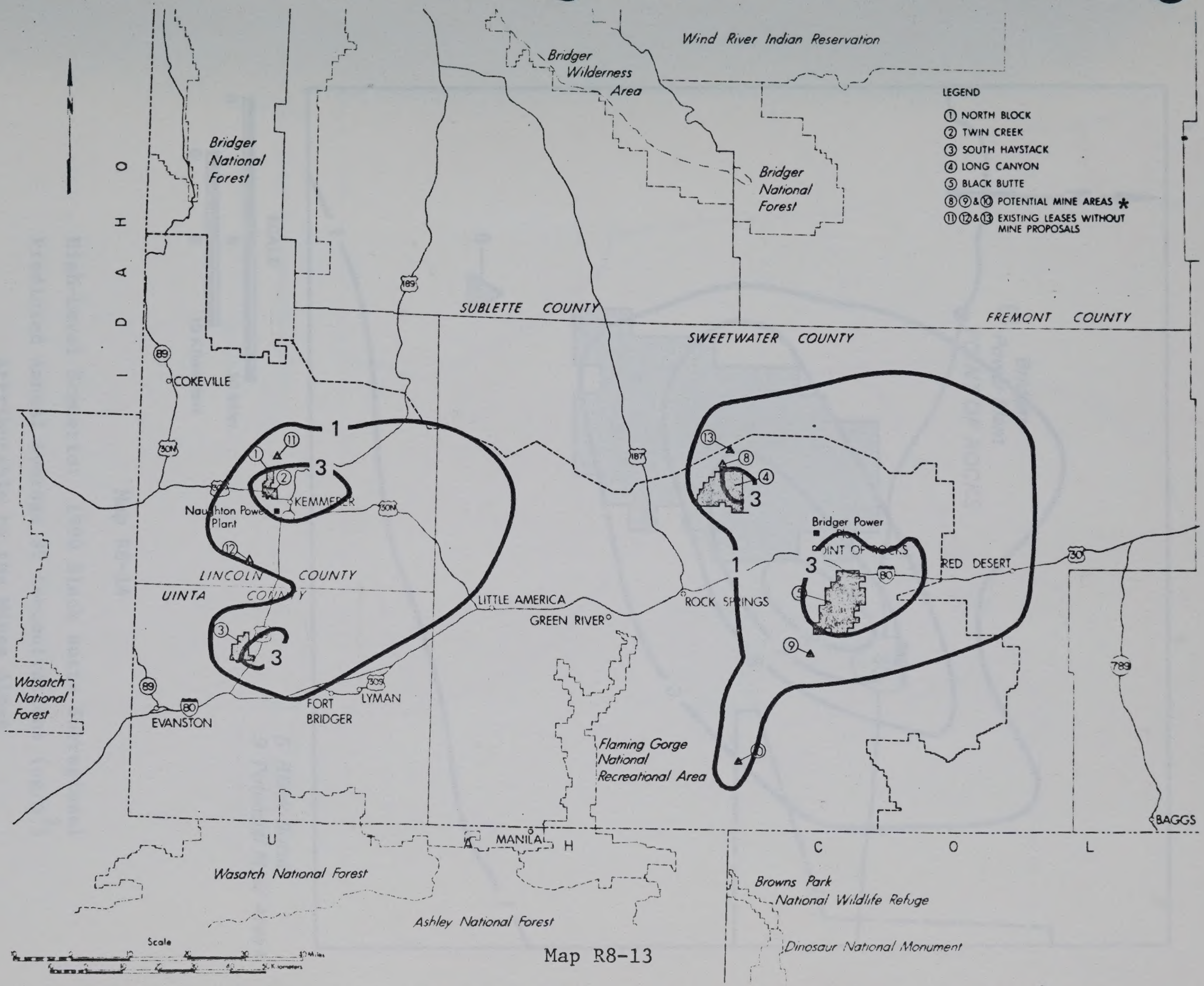
801145
804050


N
3
1
10
UTAH
COLORADO
10 Potential Mine Area
SCALE
0
5
10 Miles
0
5
10 Kilometers

Map R8-12

High-Level Scenario: 1985 Subregional Predicted Annual Average SP Concentrations ($\mu g/m^3$) About a Potential Mine Area Attributable to the Mines Alone

804097

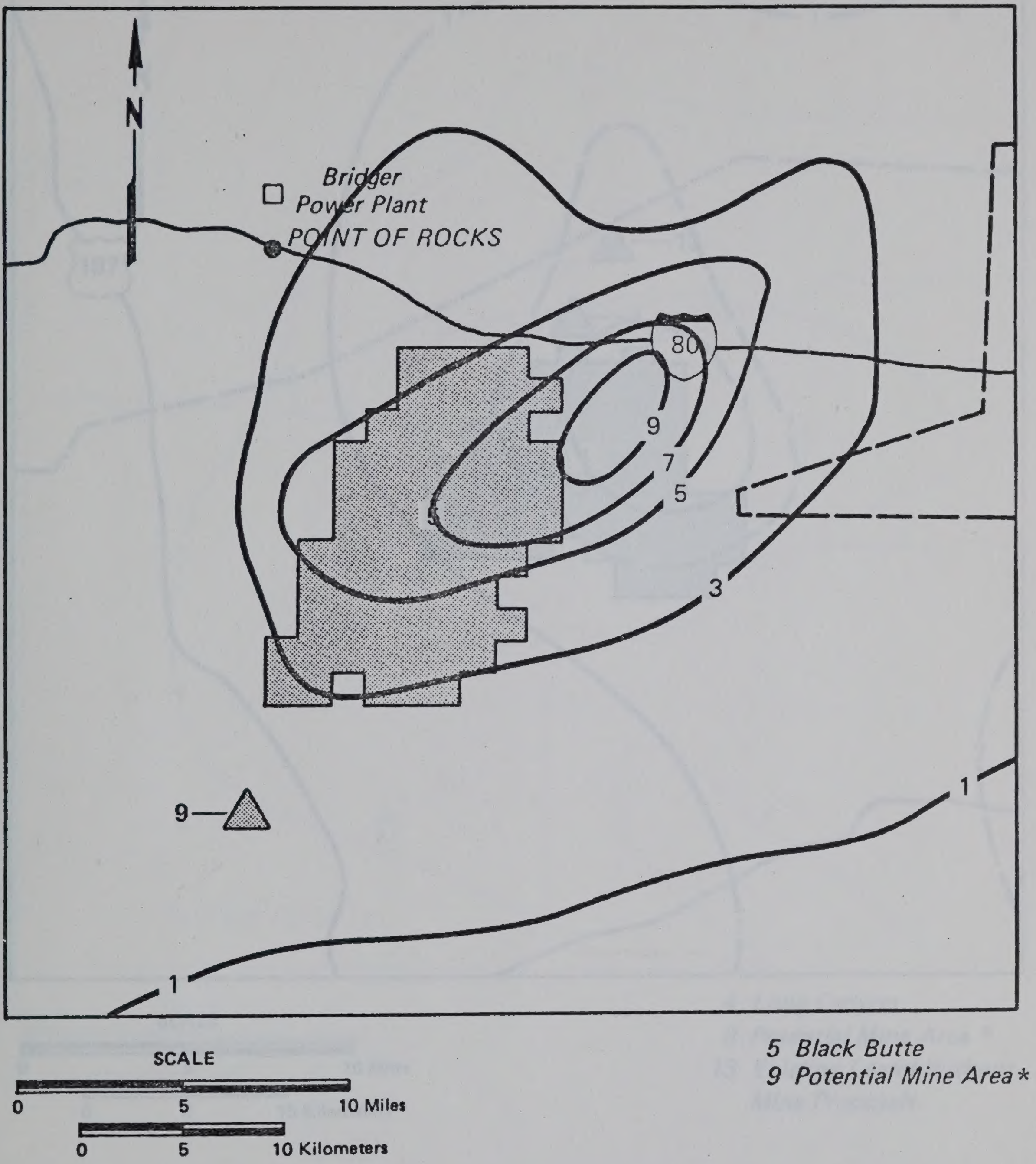

Wind River Indian Reservation
Bridger Wilderness Area
Bridger National Forest
Bridger National Forest
LEGEND
① NORTH BLOCK
② TWIN CREEK
③ SOUTH HAYSTACK
④ LONG CANYON
⑤ BLACK BUTTE
⑧⑨&⑩ POTENTIAL MINE AREAS *
⑪⑫&⑬ EXISTING LEASES WITHOUT MINE PROPOSALS
IDAHO
SUBLETTE COUNTY
FREMONT COUNTY
SWEETWATER COUNTY
COKEVILLE
189
89
30N
187
1
3
KEMMERER
Naughton Power Plant
LINCOLN COUNTY
UINTA COUNTY
LITTLE AMERICA
GREEN RIVER
ROCK SPRINGS
Bridger Power Plant
POINT OF ROCKS
RED DESERT
30
80
789
Wasatch National Forest
EVANSTON
FORT BRIDGER
LYMAN
Flaming Gorge National Recreational Area
BAGGS
MANILA
U
H
C
O
L
Wasatch National Forest
Ashley National Forest
Browns Park National Wildlife Refuge
Dinosaur National Monument
Scale
Miles
Kilometers

Map R8-13

High-Level Scenario: 1990 Predicted Annual Average SP Concentrations ($\mu g/m^3$)

Attributable to the Mines Alone

*Equivalent to "mine areas of interest."

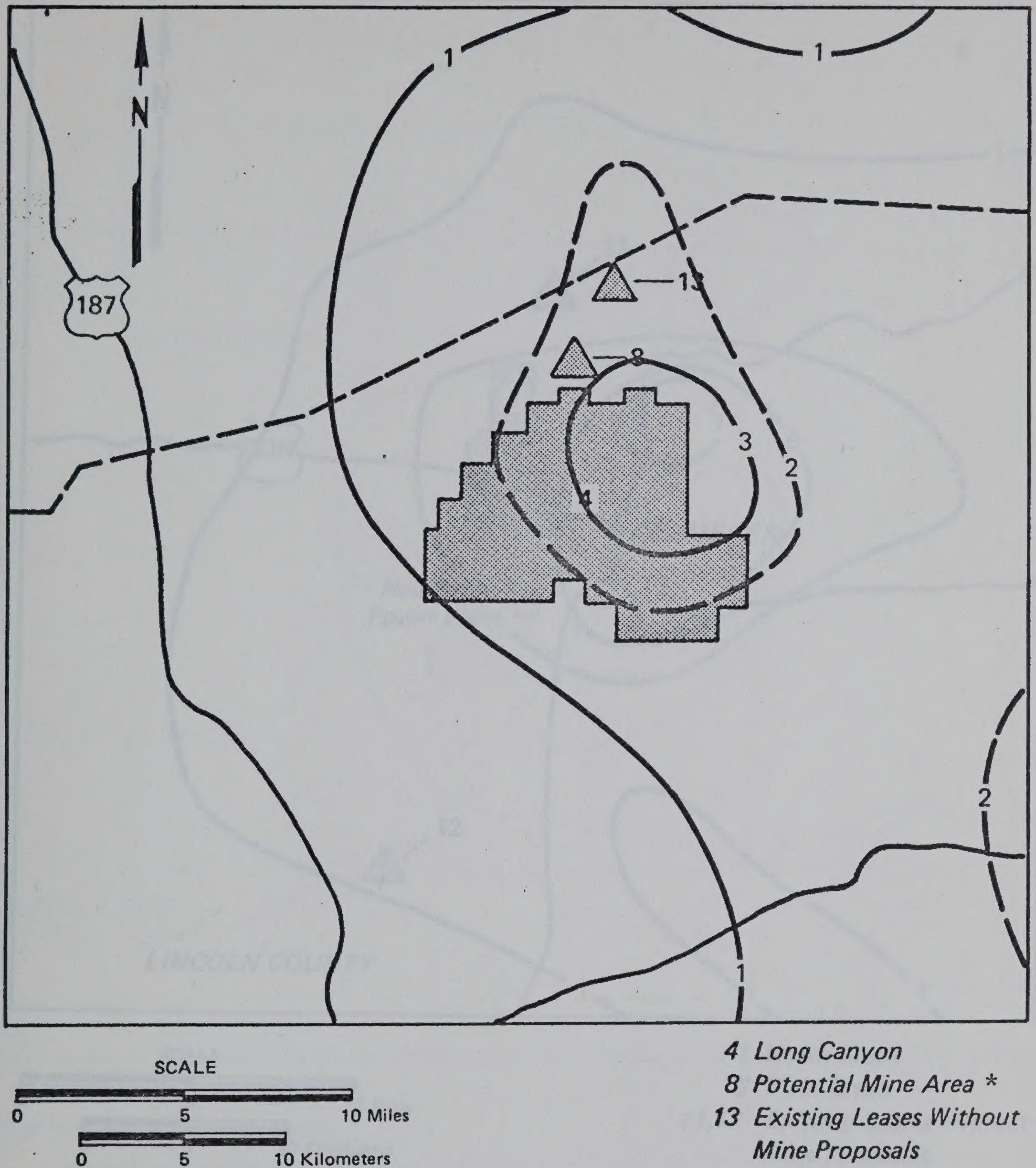

N
Bridger
Power Plant
POINT OF ROCKS
80
9
7
5
5
3
1
1
9
SCALE
0
5
10 Miles
0
5
10 Kilometers
5 Black Butte
9 Potential Mine Area*

Map R8-14

High-Level Scenario: 1990 Black Butte Subregional Predicted Annual Average SP Concentrations ($\mu g/m^3$) Attributable to the Mines Alone

*Equivalent to "mine areas of interest."

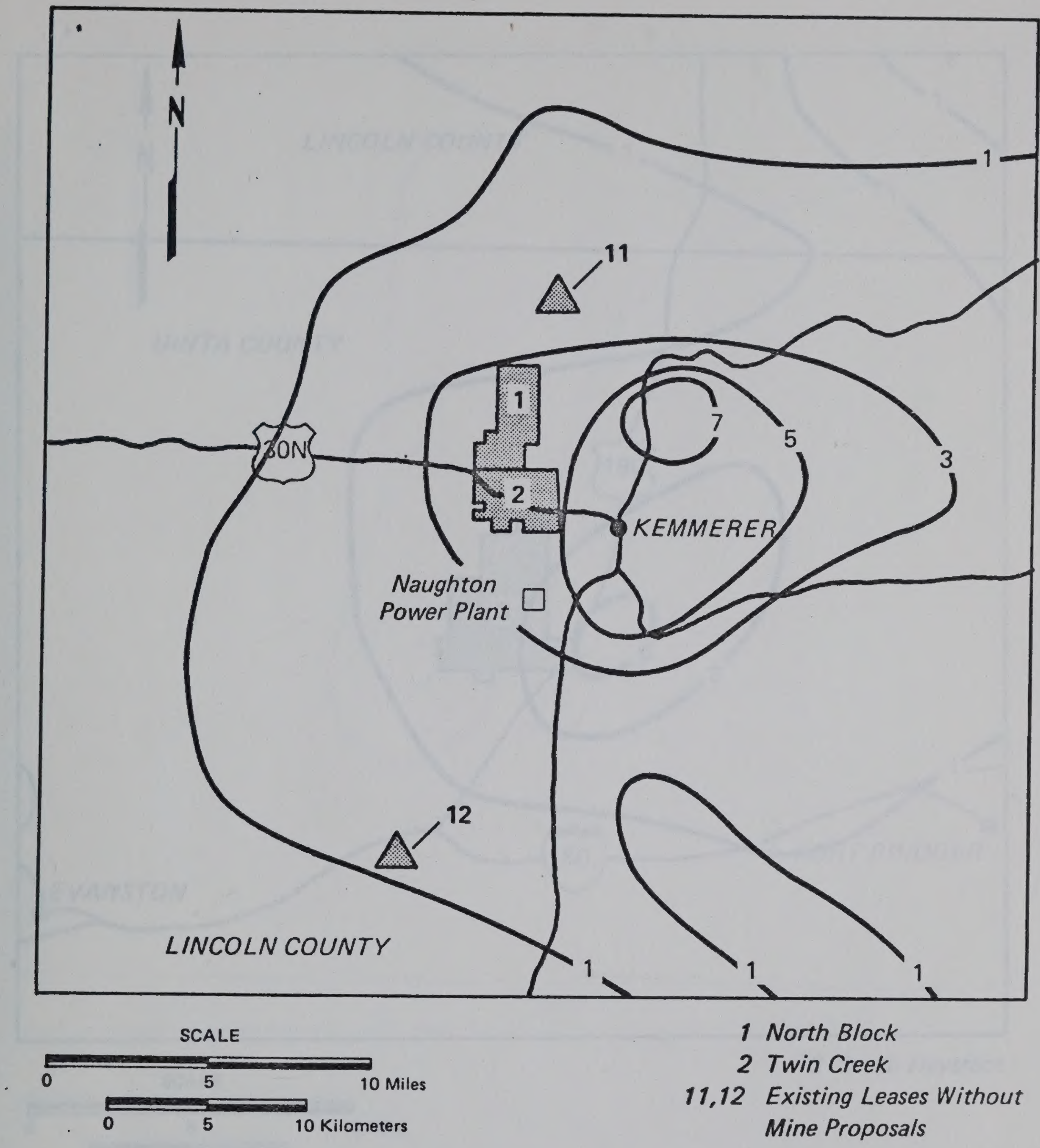
801144
804055


N
187
1
1
13
8
3
2
4
2
1
SCALE
0
5
10 Miles
0
5
10 Kilometers
4 Long Canyon
8 Potential Mine Area *
13 Existing Leases Without Mine Proposals

Map R8-15

High-Level Scenario: 1990 Long Canyon Subregional Predicted Annual Average SP Concentrations (μg/m^3) Attributable to the Mines Alone

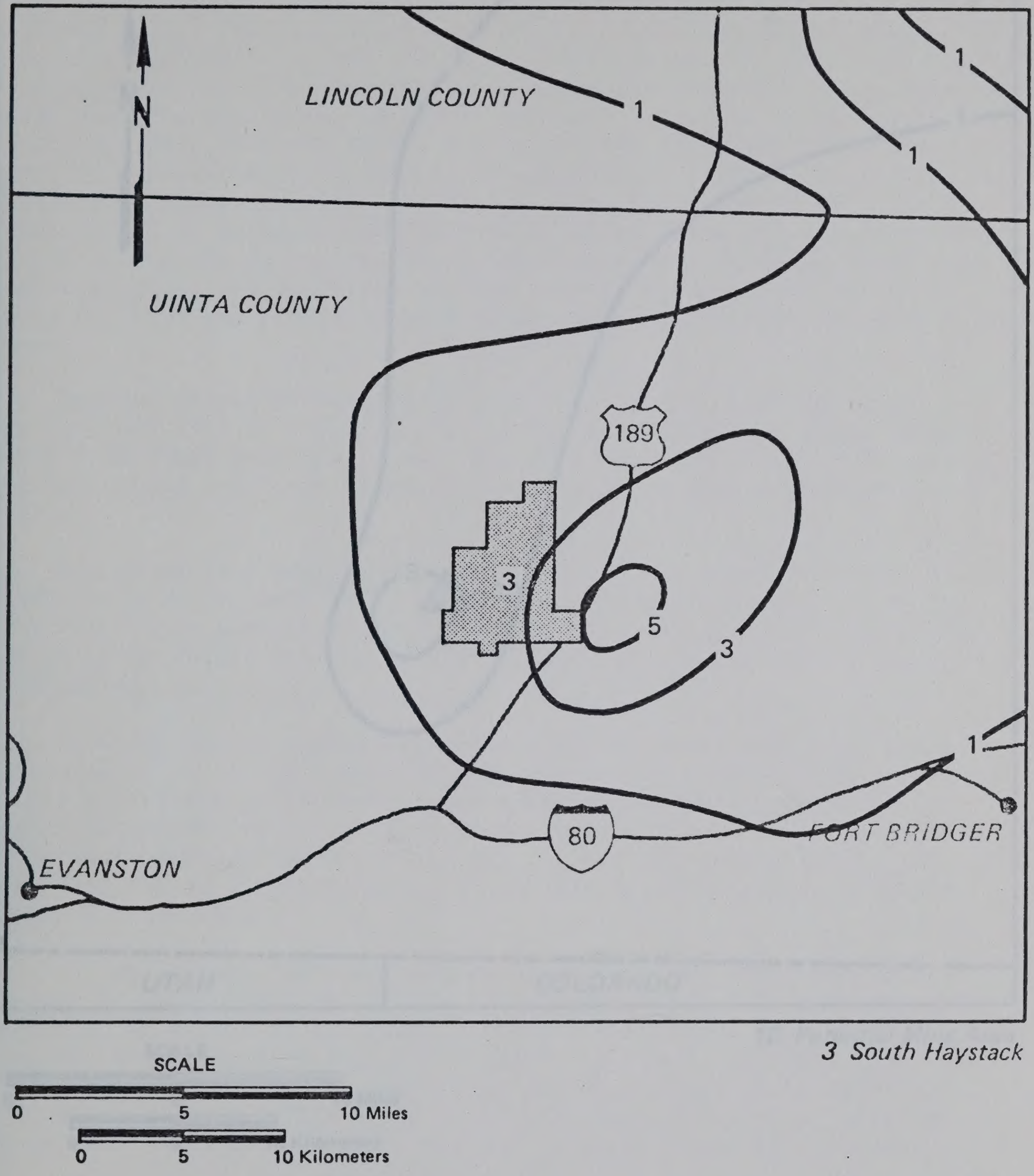
*Equivalent to "mine areas of interest."


N
1
11
30N
1
2
7
5
3
KEMMERER
Naughton Power Plant
12
LINCOLN COUNTY
1
1
1
SCALE
0
5
10 Miles
0
5
10 Kilometers
1 North Block
2 Twin Creek
11,12 Existing Leases Without Mine Proposals

Map R8-16

High-Level Scenario: 1990 North Block-Twin Creek Subregional Predicted Annual Average SP Concentrations ($\mu g/m^3$) Attributable to the Mines Alone

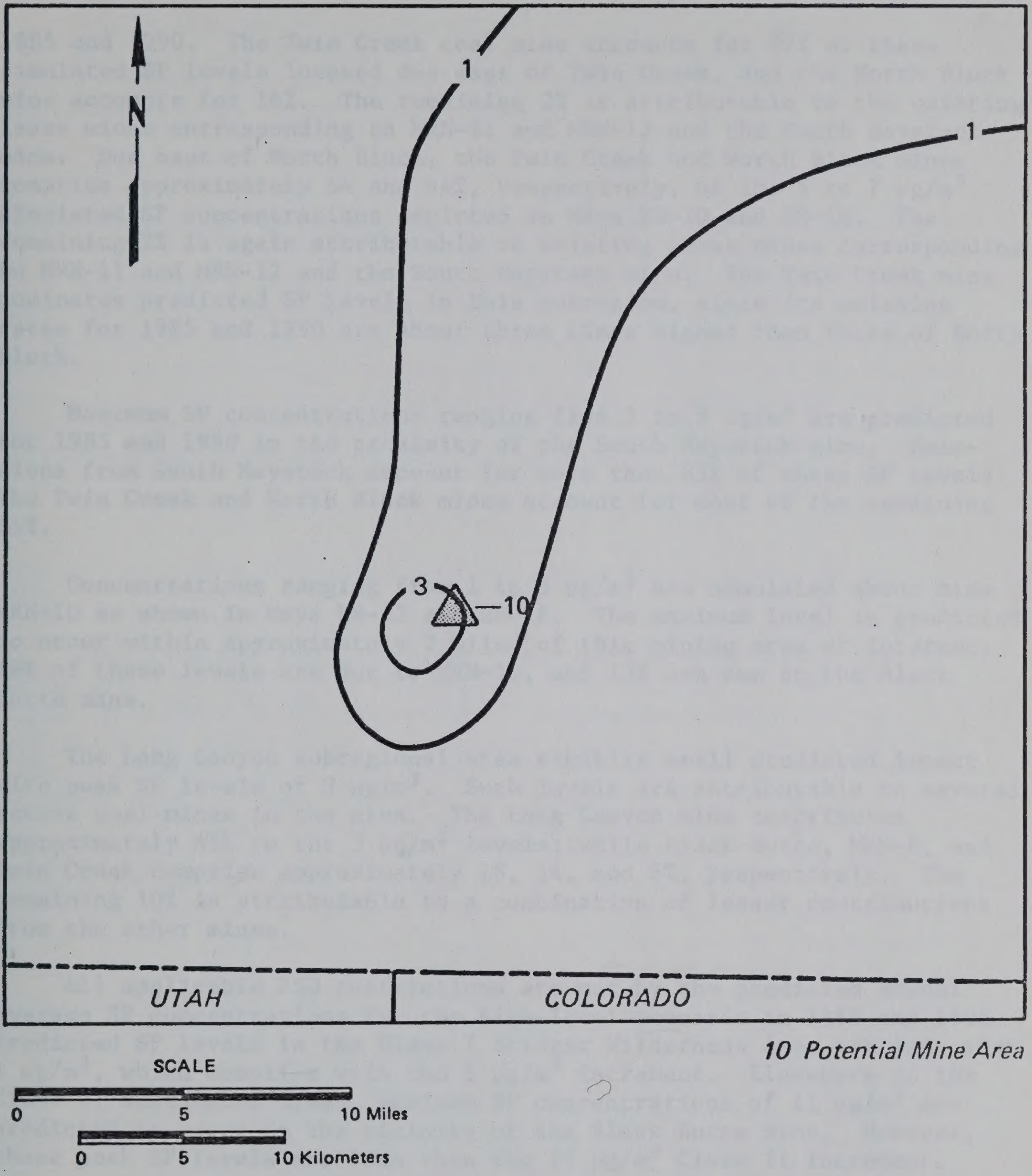
4140
4093


LINCOLN COUNTY
N
UINTA COUNTY
1
1
1
1
189
3
5
3
80
EVANSTON
FORT BRIDGER
3 South Haystack
SCALE
0
5
10 Miles
0
5
10 Kilometers

Map R8-17

High-Level Scenario: 1990 South Haystack Subregional
Predicted Annual Average SP Concentrations ($\mu g/m^3$)
Attributable to the Mines Alone

801145
804049


N
1
1
3
10
UTAH
COLORADO
10 Potential Mine Area
SCALE
0
5
10 Miles
0
5
10 Kilometers

Map R8-18

High-Level Scenario: 1990 Subregional

Predicted Annual Average SP Concentrations ($\mu g/m^3$) About a Potential Mine Area Attributable to the Mines Alone

1985 and 1990. The Twin Creek coal mine accounts for 82% of these simulated SP levels located due east of Twin Creek, and the North Block mine accounts for 16%. The remaining 2% is attributable to the existing lease mines corresponding to MRN-11 and MRN-12 and the South Haystack mine. Due east of North Block, the Twin Creek and North Block mines comprise approximately 54 and 44%, respectively, of the 5 to 7 μg/m^3 simulated SP concentrations depicted in Maps R8-10 and R8-16. The remaining 2% is again attributable to existing lease mines corresponding to MRN-11 and MRN-12 and the South Haystack mine. The Twin Creek mine dominates predicted SP levels in this subregion, since its emission rates for 1985 and 1990 are about three times higher than those of North Block.

Maximum SP concentrations ranging from 3 to 5 μg/m^3 are predicted for 1985 and 1990 in the proximity of the South Haystack mine. Emissions from South Haystack account for more than 85% of these SP levels. The Twin Creek and North Block mines account for most of the remaining 15%.

Concentrations ranging from 1 to 3 μg/m^3 are simulated about mine MRN-10 as shown in Maps R8-12 and R8-18. The maximum level is predicted to occur within approximately 2 miles of this mining area of interest; 78% of these levels are due to MRN-10, and 13% are due to the Black Butte mine.

The Long Canyon subregional area exhibits small predicted impact with peak SP levels of 3 μg/m^3. Such levels are attributable to several active coal mines in the area. The Long Canyon mine contributes approximately 45% to the 3 μg/m^3 levels; while Black Butte, MRN-8, and Twin Creek comprise approximately 18, 14, and 8%, respectively. The remaining 10% is attributable to a combination of lesser contributions from the other mines.

All applicable PSD restrictions are met by the predicted annual average SP concentrations for the high-level scenario in 1985 and 1990. Predicted SP levels in the Class I Bridger Wilderness Area are less than 1 μg/m^3, which complies with the 5 μg/m^3 increment. Elsewhere in the Class II designated areas, maximum SP concentrations of 11 μg/m^3 are predicted to occur in the vicinity of the Black Butte mine. However, these peak SP levels are less than the 19 μg/m^3 Class II increment.

The Flaming Gorge Recreational Area shown in Maps R8-7 and R8-13 and the Fossil Butte National Monument, located approximately 10 miles northwest of Kemmerer, are currently designated Class II areas, but may be reclassified to Class I. However, predicted SP concentrations in these areas are approximately 1 μg/m^3 in 1985 and 1990, well below the Class I 5 μg/m^3 increment.

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Annual average SP concentrations of less than 1 μg/m^3 in 1985 and 1990 are predicted to occur in the vicinity of the NA trona patch, located 6 miles north of Green River. The predicted mine impact is less than 1% of the 260 μg/m^3 federal standard.

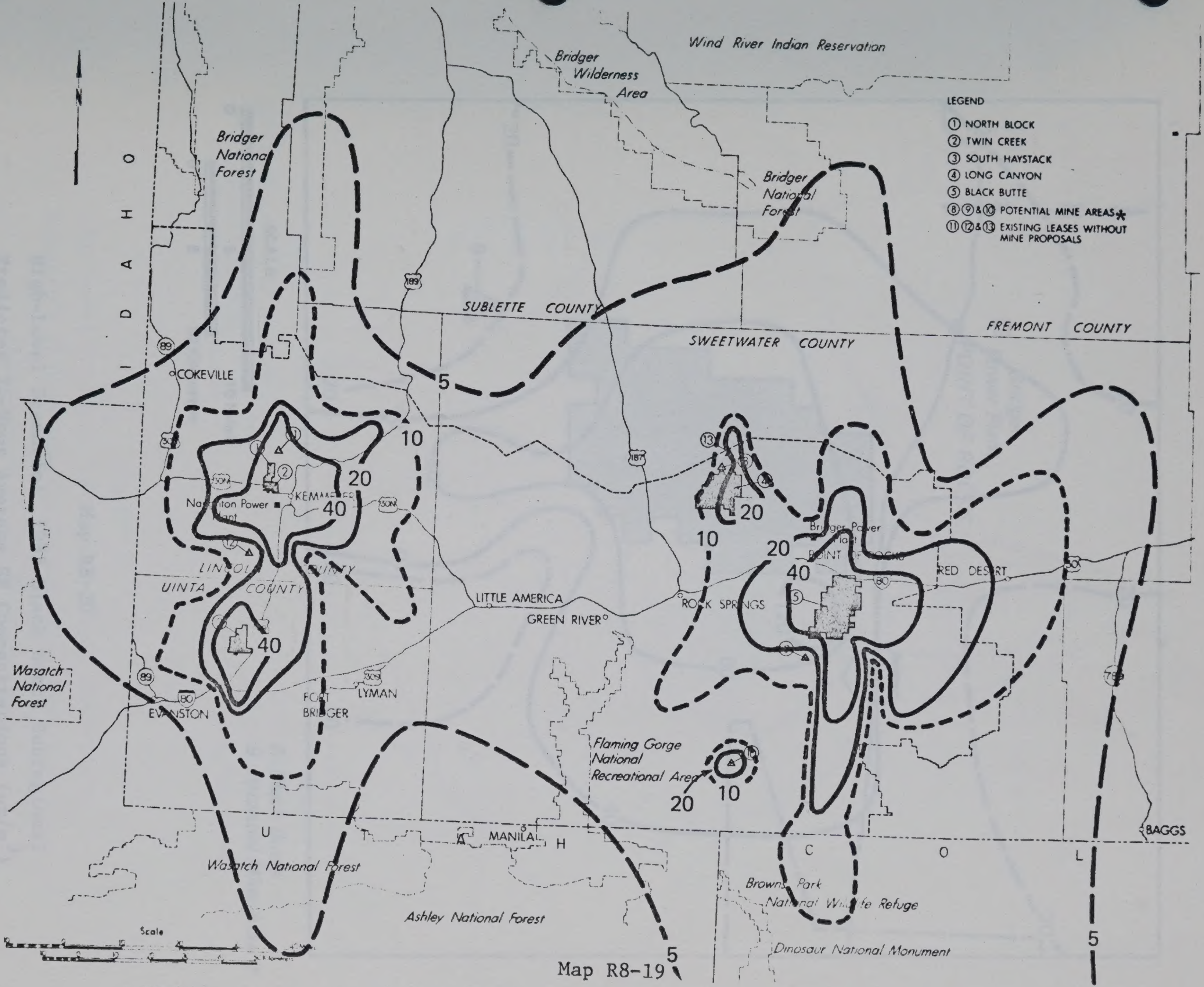
Model Predictions of Worst-Case 24-Hour Impact on SP Concentrations

Worst-case predictions of regional 24-hour average SP concentrations associated with the high-level scenario for 1985 and 1990 are presented in Maps R8-19 through R8-30. The meteorology used to simulate these concentrations represents a combination of Tables R4-60 and R4-61, which correspond to worst-case atmospheric dispersion conditions and wind direction persistence recorded at the Rock Springs and Fort Bridger meteorological stations, respectively, over a five-year period.

Model Predictions of 24-Hour Average Impact on SP Concentrations for 1985

Predicted SP impact from the high level of coal development alone is depicted in Maps R8-19 and R8-30. Note that the concentration pattern depicted in Maps R8-19 through R8-30 represents a composite of the maximum model predictions for all wind directions and that the assumption is made that predicted levels at individual receptors could occur at least once per year. Regionally, simulated SP levels range from 5 to 120 μg/m^3, although somewhat higher concentrations are predicted to occur within 2 miles south of the Twin Creek mine. In the eastern portion of the ES region, estimated emissions emanating from the Black Butte mine dominate predicted impact. Although several underground mines in this area are operational in 1985, the sum of their emission rates is less than 15% of the Black Butte mine emission rate. Therefore, the skewing effect illustrated by the isopleths is associated, in general, with the wind direction that lines up the Black Butte mine with a given receptor. The other mines in this area do influence concentrations predicted very close (within 3 to 5 miles) to each individual mine, but their contribution elsewhere is insignificant. Simulated SP concentrations in the vicinity of the Black Butte, Long Canyon, Winton, and Reliance mines are presented in Maps R8-20 and R8-21. Predicted concentrations in the Long Canyon subregion (including the two smaller underground mines) are low, with maximum levels of approximately 20 μg/m^3. An east-southeast wind direction dispersing emissions from the Black Butte mine accounts for simulated levels of 20 to 40 μg/m^3 approximately 9 miles southeast of Long Canyon. Peak SP levels of 20 μg/m^3 are predicted to occur about the Long Canyon mine attributable mostly to Long Canyon emissions; the other mines in this subregion have

8143 B
80

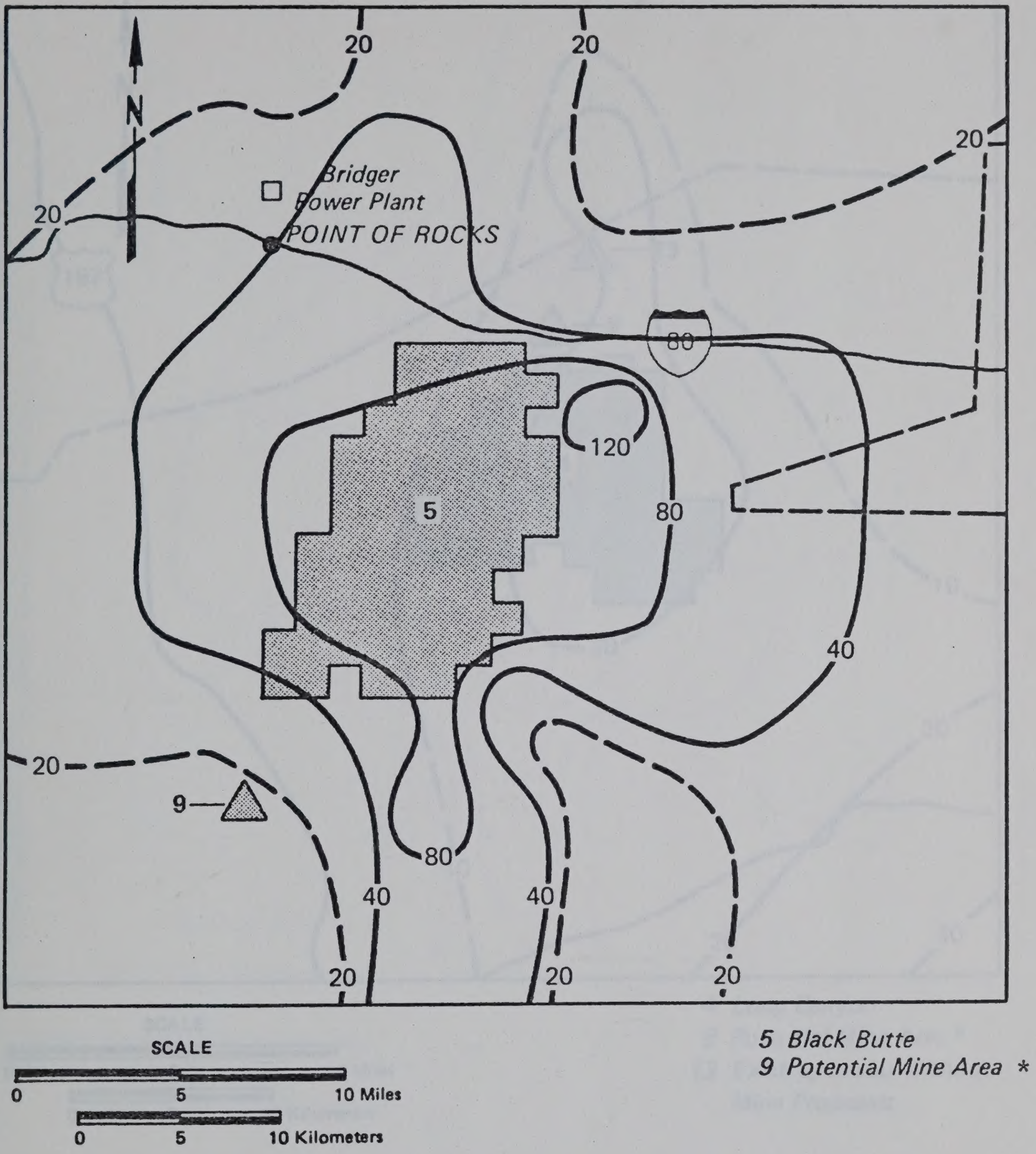

Wind River Indian Reservation
Bridger Wilderness Area
Bridger National Forest
Bridger National Forest
LEGEND
① NORTH BLOCK
② TWIN CREEK
③ SOUTH HAYSTACK
④ LONG CANYON
⑤ BLACK BUTTE
⑧⑨&⑩ POTENTIAL MINE AREAS*
⑪⑫&⑬ EXISTING LEASES WITHOUT MINE PROPOSALS
I D A H O
SUBLETTE COUNTY
SWEETWATER COUNTY
FREMONT COUNTY
COKEVILLE
KEMMERER
Naughton Power Plant
LINCOLN COUNTY
UINTA COUNTY
LITTLE AMERICA
GREEN RIVER
ROCK SPRINGS
Bridger Power Plant
POINT OF ROCKS
RED DESERT
EVANSTON
FORT BRIDGER
LYMAN
Wasatch National Forest
Flaming Gorge National Recreational Area
MANILA
U T A H
C O L
BAGGS
Browns Park National Wildlife Refuge
Ashley National Forest
Dinosaur National Monument
Wasatch National Forest
Scale
5
10
20
40
40
20
10
20
40
20
10
20
10
5
5

Map R8-19

High-Level Scenario: 1985 Predicted 24-Hour Average SP Concentrations ($\mu g/m^3$)

Attributable to the Mines Alone

*Equivalent to "mine areas of interest."

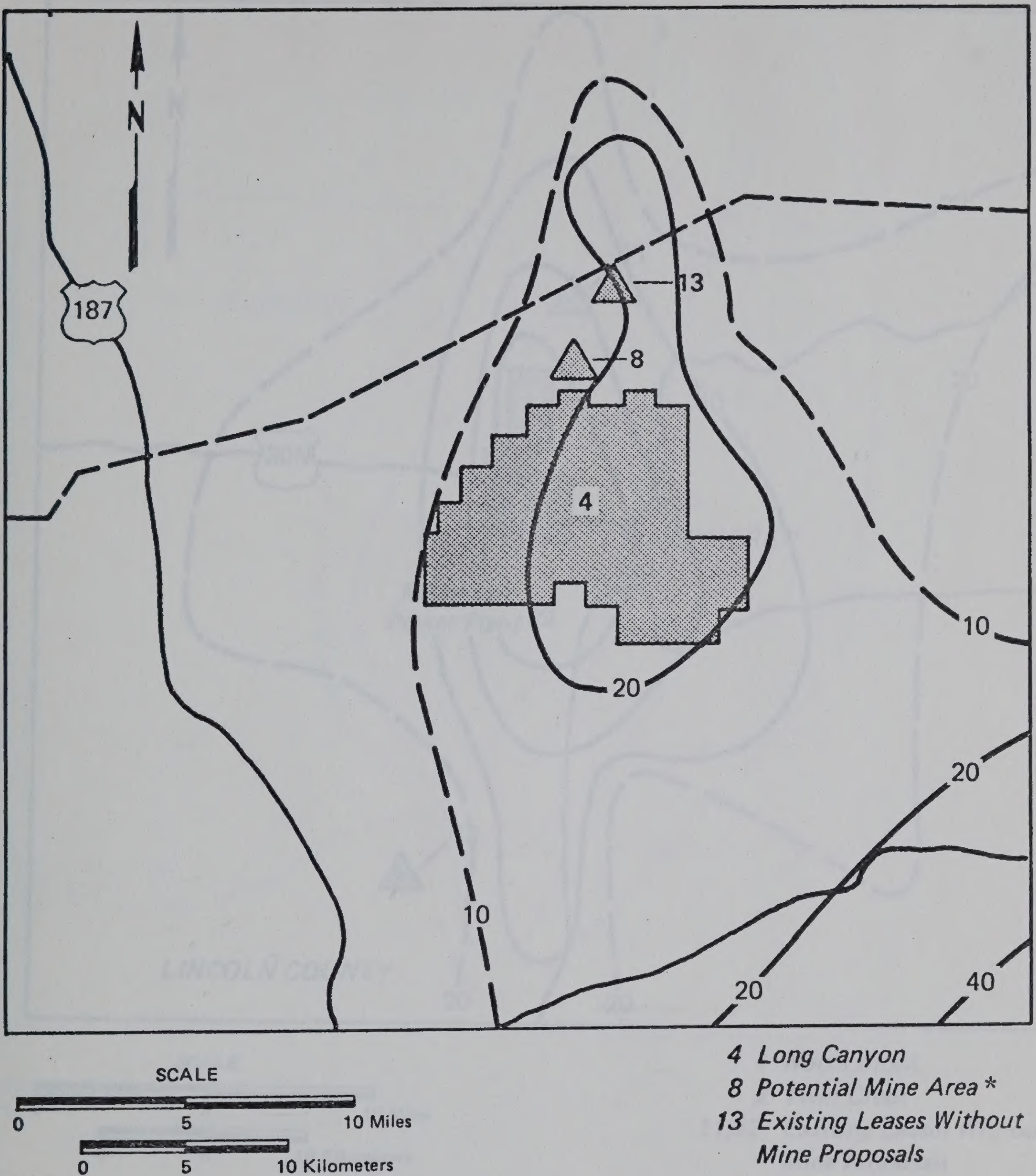

N
20
20
20
20
Bridger
Power Plant
POINT OF ROCKS
80
120
5
80
40
20
9
80
40
40
20
20
20
SCALE
0
5
10 Miles
0
5
10 Kilometers
5 Black Butte
9 Potential Mine Area *

Map R8-20

High-Level Scenario: 1985 Black Butte Subregional Predicted 24-Hour Average SP Concentrations ($\mu g/m^3$) Attributable to the Mines Alone

*Equivalent to "mine area of interest."

801144
804052


N
187
13
8
4
10
20
20
10
20
40
SCALE
0
5
10 Miles
0
5
10 Kilometers
4 Long Canyon
8 Potential Mine Area *
13 Existing Leases Without Mine Proposals

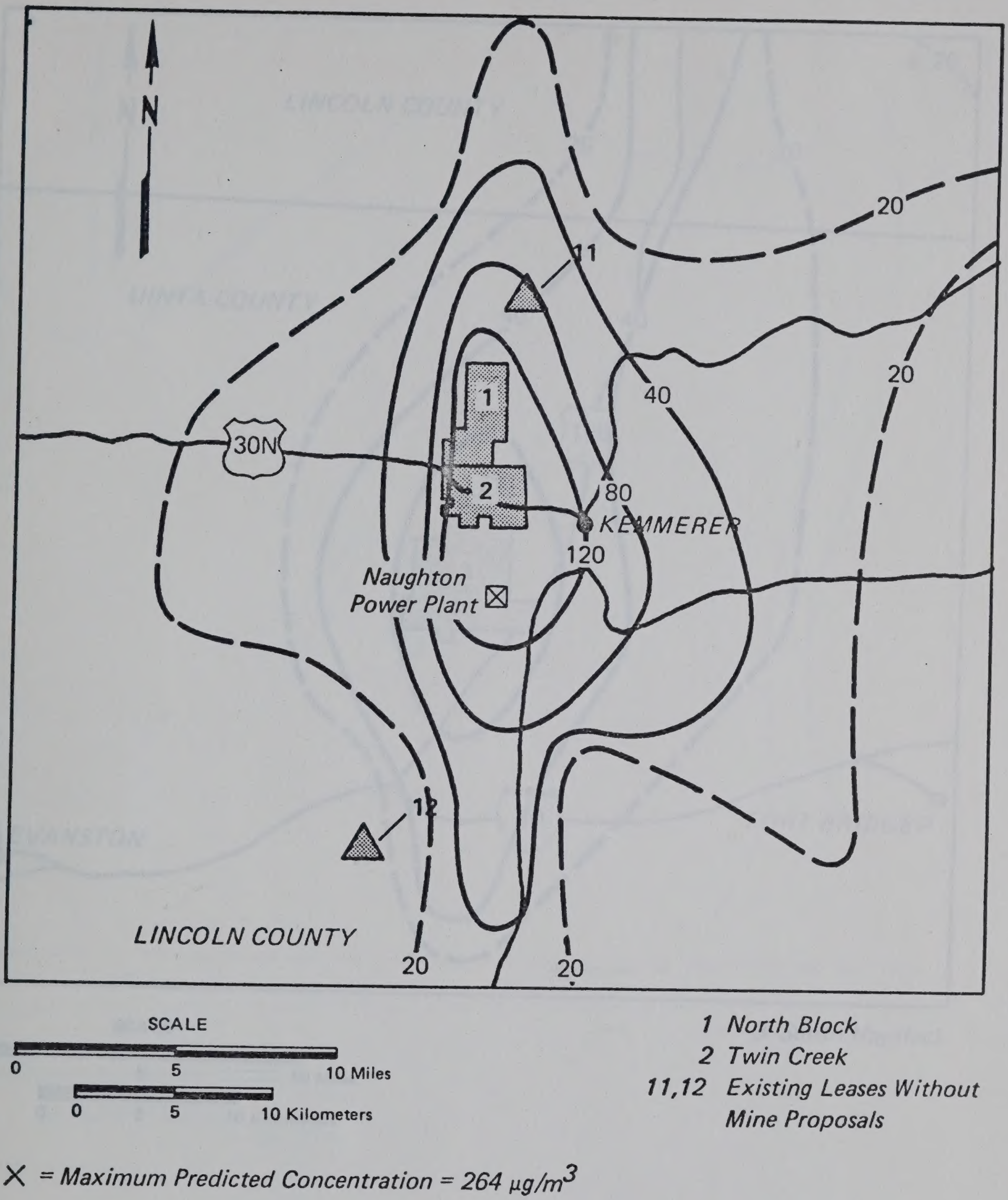
Map R8-21

High-Level Scenario: 1985 Long Canyon Subregional

Predicted 24-Hour Average SP Concentrations ($\mu g/m^3$)

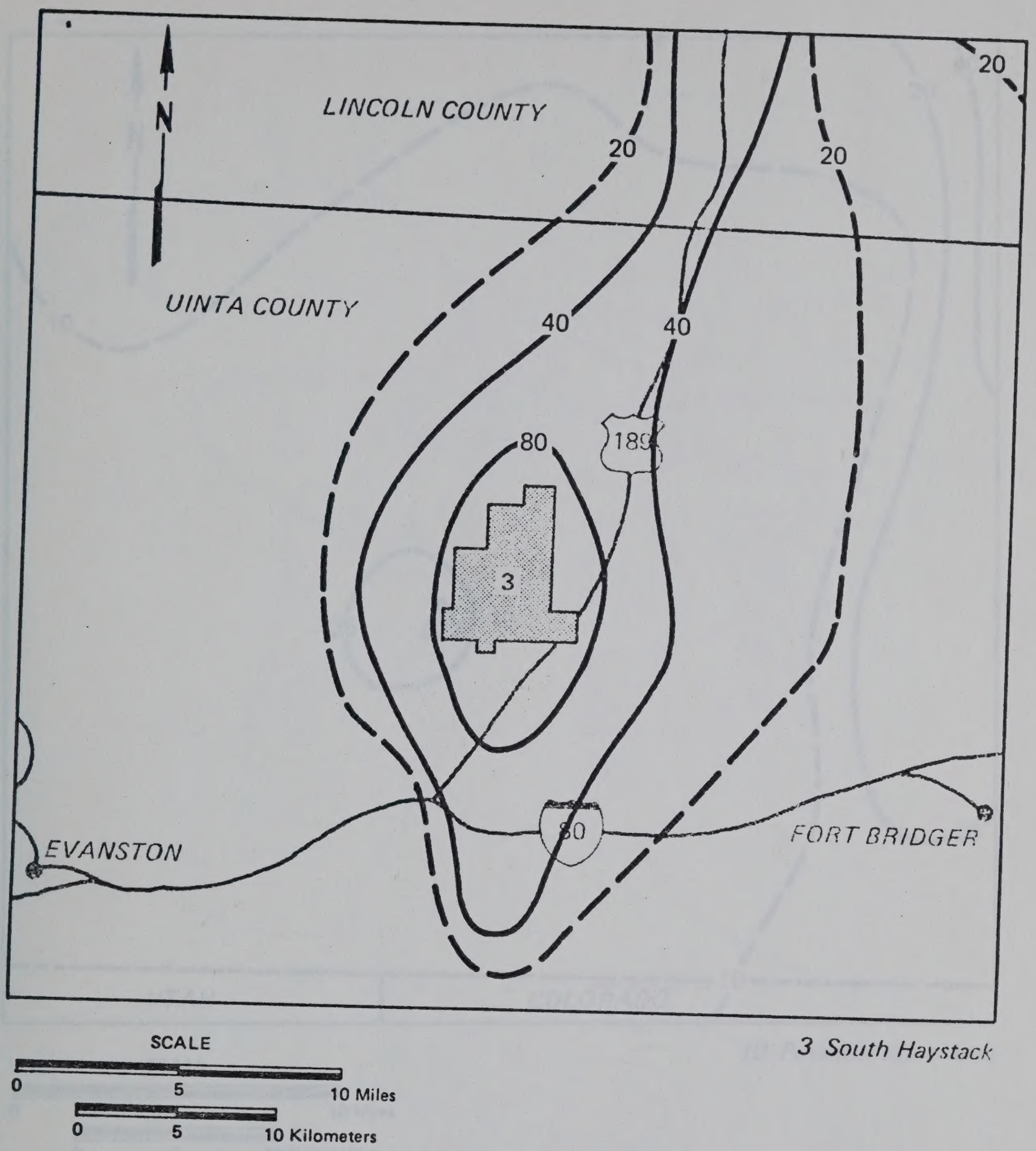
Attributable to the Mines Alone

*Equivalent to "mine areas of interest."


N
20
11
20
40
1
30N
2
80
KEMMERER
120
Naughton Power Plant
12
LINCOLN COUNTY
20
20
SCALE
0 5 10 Miles
0 5 10 Kilometers
1 North Block
2 Twin Creek
11,12 Existing Leases Without Mine Proposals
X = Maximum Predicted Concentration = 264 μg/m3

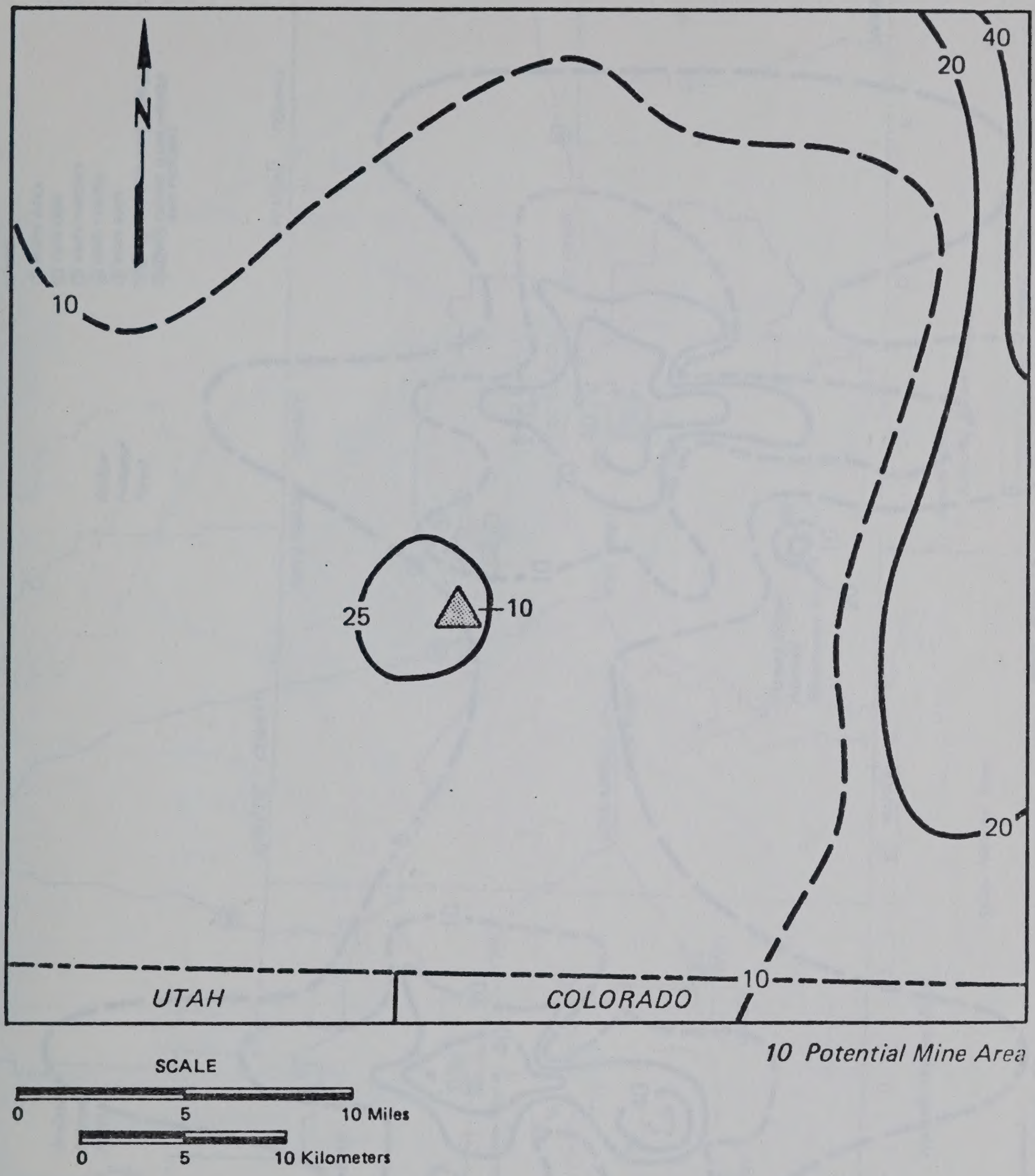
Map R8-22

High-Level Scenario: 1985 North Block-Twin Creek Subregional Predicted 24-Hour Average SP Concentrations ($\mu g/m^3$) Attributable to the Mines Alone


N
LINCOLN COUNTY
UINTA COUNTY
20
20
20
40
40
80
189
3
80
EVANSTON
FORT BRIDGER
SCALE
0
5
10 Miles
0
5
10 Kilometers
3 South Haystack

Map R8-23

High-Level Scenario: 1985 South Haystack Subregional
Predicted 24-Hour Average SP Concentrations
Attributable to the Mines Alone


N
10
20
40
25
10
20
10
UTAH
COLORADO
10 Potential Mine Area
SCALE
0
5
10 Miles
0
5
10 Kilometers

Map R8-24

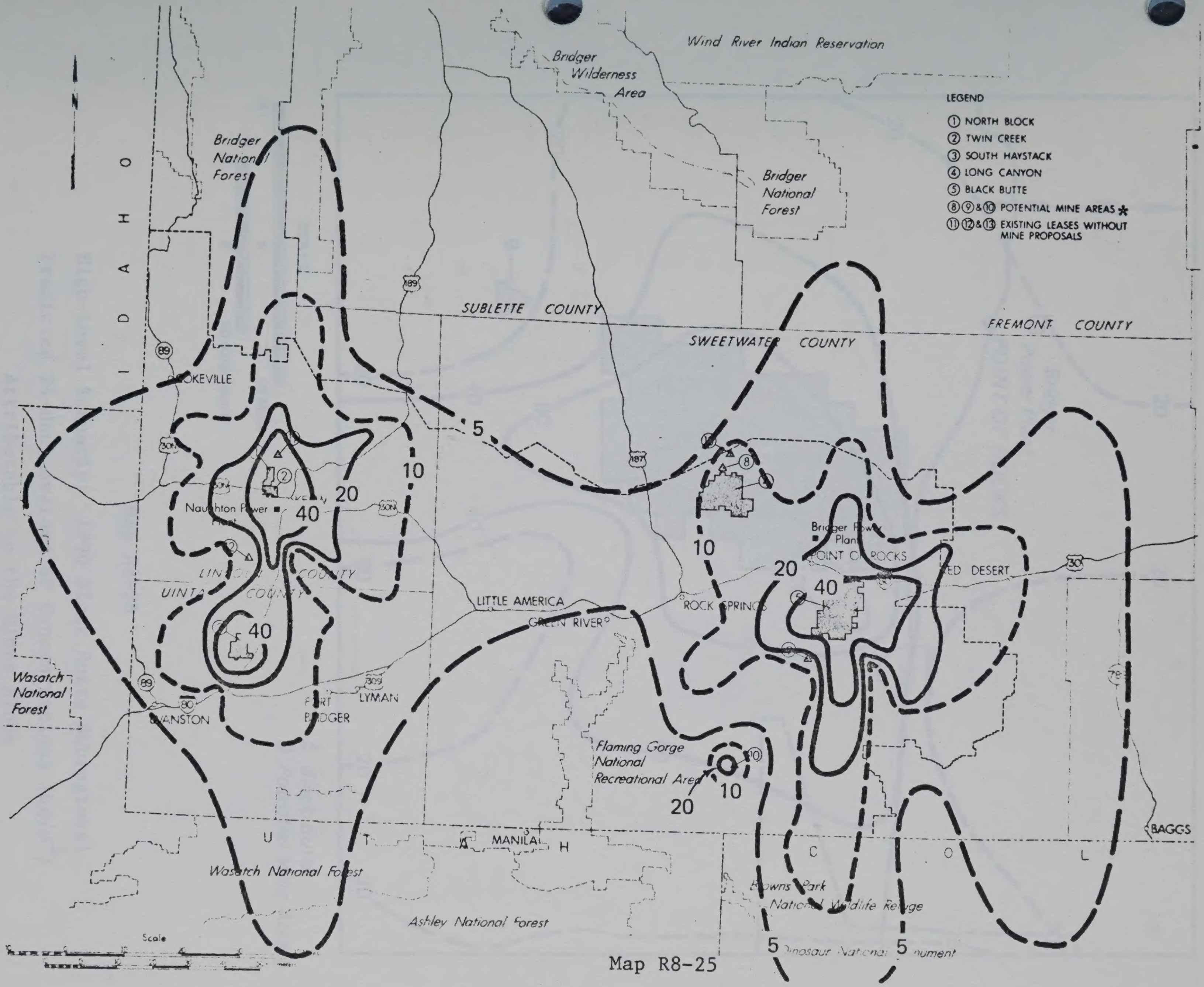
High-Level Scenario: 1985 Subregional

Predicted 24-Hour Average SP Concentrations ($\mu g/m^3$)

Attributable to the Mines Alone

801146
804058

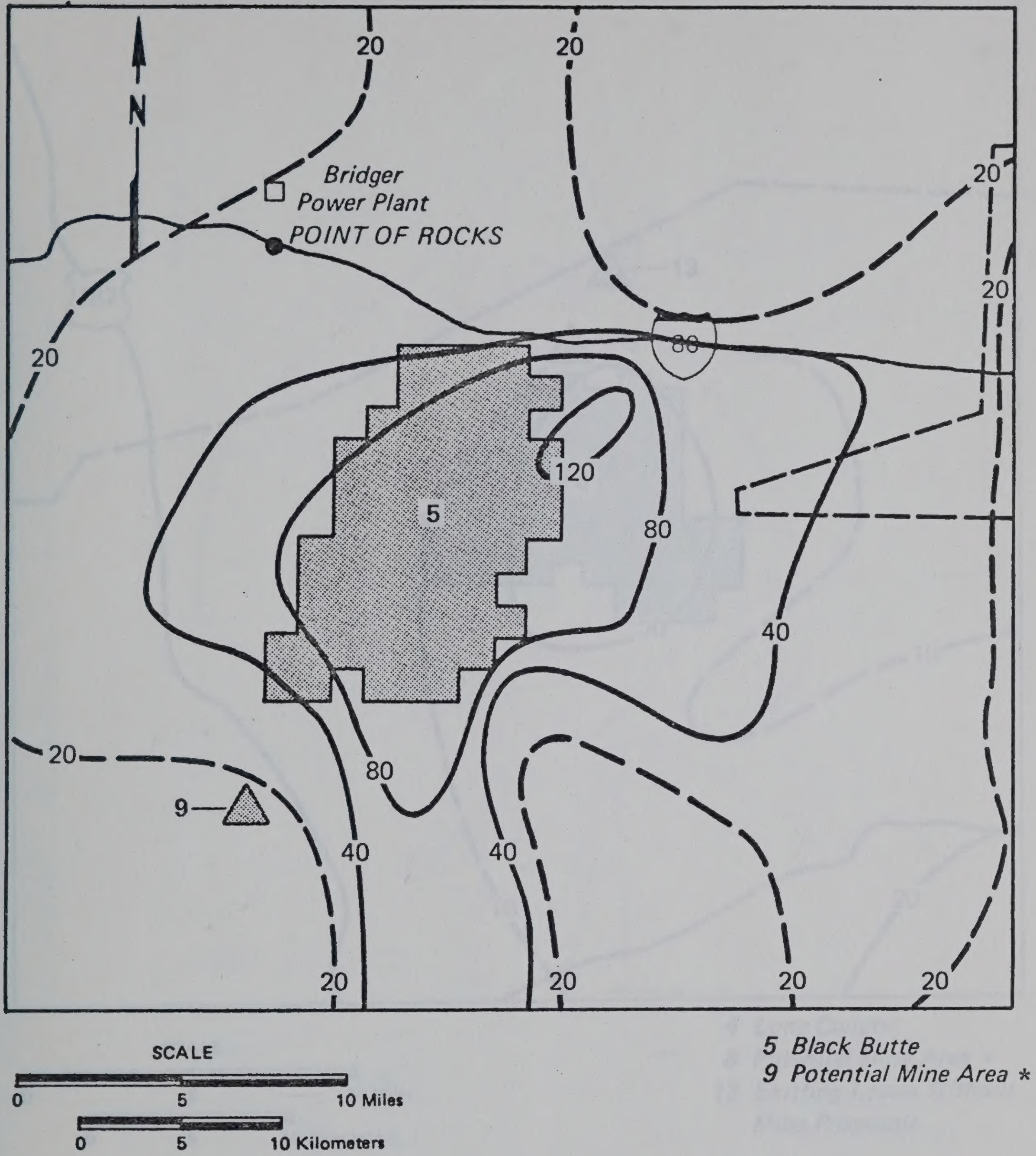
804092
8041


Wind River Indian Reservation
Bridger Wilderness Area
Bridger National Forest
Bridger National Forest
LEGEND
① NORTH BLOCK
② TWIN CREEK
③ SOUTH HAYSTACK
④ LONG CANYON
⑤ BLACK BUTTE
⑧⑨&⑩ POTENTIAL MINE AREAS *
⑪⑫&⑬ EXISTING LEASES WITHOUT MINE PROPOSALS
IDAHO
189
SUBLETTE COUNTY
FREMONT COUNTY
SWEETWATER COUNTY
89
KEMMERER
COKEVILLE
5
10
20
40
Naughton Power Plant
187
Bridger Power Plant
POINT OF ROCKS
RED DESERT
30
10
20
40
LINCOLN COUNTY
UINTA COUNTY
LITTLE AMERICA
GREEN RIVER
ROCK SPRINGS
40
89
80
EVANSTON
FORT BRIDGER
LYMAN
Wasatch National Forest
Flaming Gorge National Recreational Area
10
20
BAGGS
U
T
A
H
MANILA
C
O
L
Wasatch National Forest
Ashley National Forest
Browns Park National Wildlife Refuge
5
Dinosaur National Monument
5
Scale

Map R8-25

High-Level Scenario: 1990 Predicted 24-Hour Average SP Concentrations ($\mu g/m^3$) Attributable to the Mines Alone

*Equivalent to "mine areas of interest."

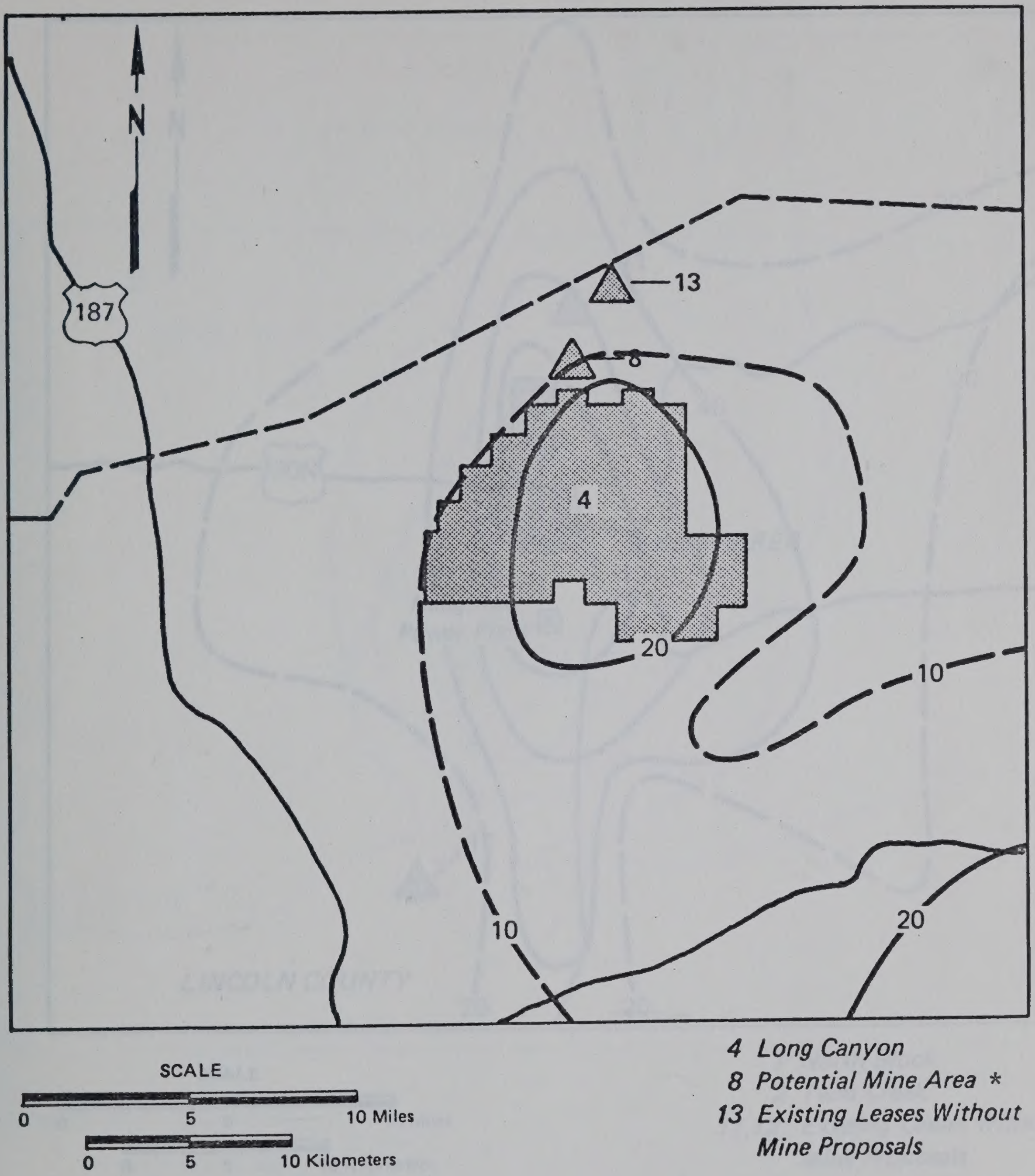

N
20
20
Bridger
Power Plant
POINT OF ROCKS
20
20
20
80
120
5
80
40
20
80
9
40
40
20
20
20
20
SCALE
0
5
10 Miles
0
5
10 Kilometers
5 Black Butte
9 Potential Mine Area *

Map R8-26

High-Level Scenario: 1990 Black Butte Subregional Predicted 24-Hour Average SP Concentrations (μg/m^3) Attributable to the Mines Alone

*Equivalent to "mine areas of interest."

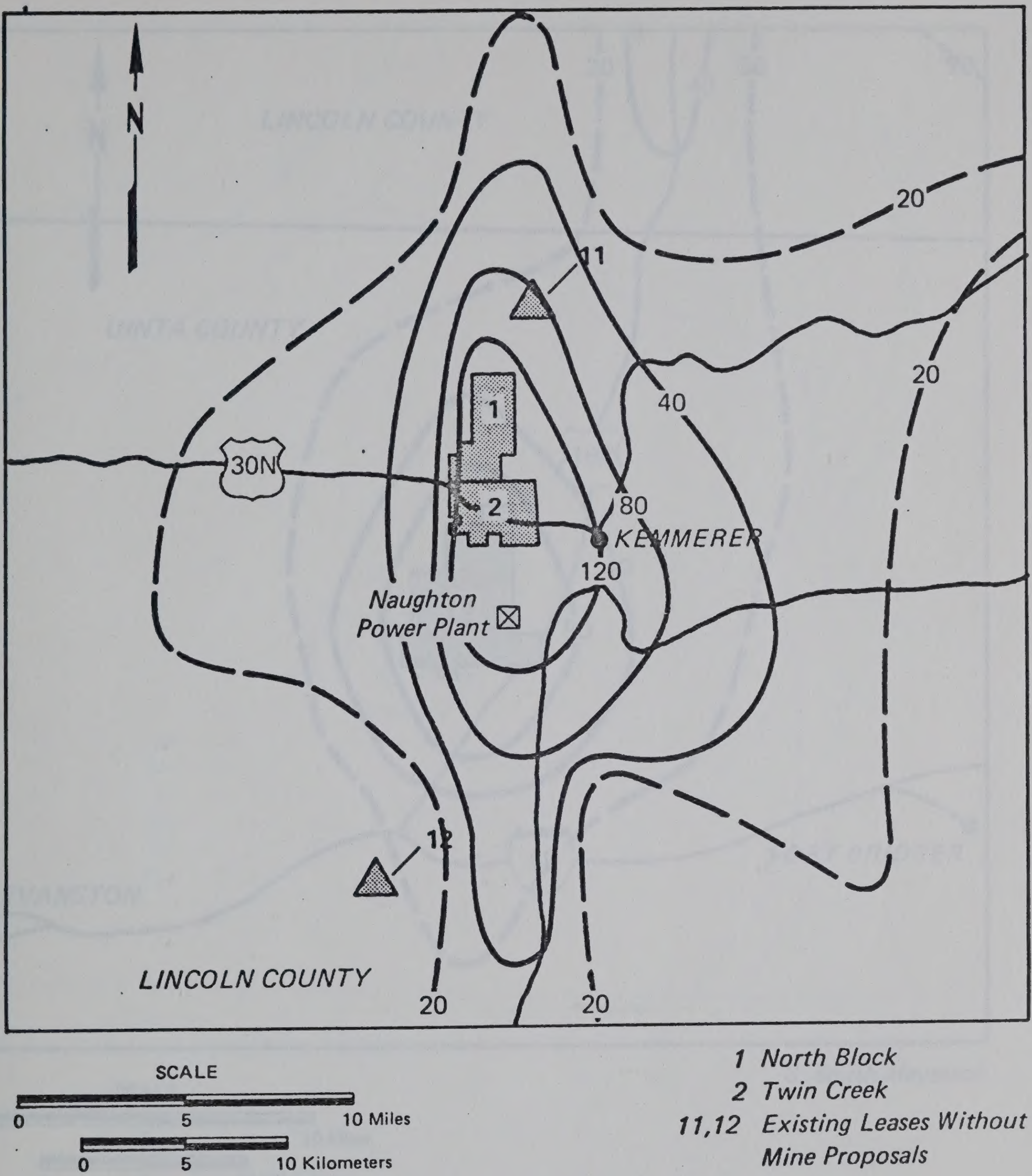
801144
804051


N
187
13
8
4
20
10
10
20
SCALE
0 5 10 Miles
0 5 10 Kilometers
4 Long Canyon
8 Potential Mine Area *
13 Existing Leases Without Mine Proposals

Map R8-27

High-Level Scenario: 1990 Long Canyon Subregional Predicted 24-Hour Average SP Concentrations (μg/m^3) Attributable to the Mines Alone

*Equivalent to "mine areas of interest."

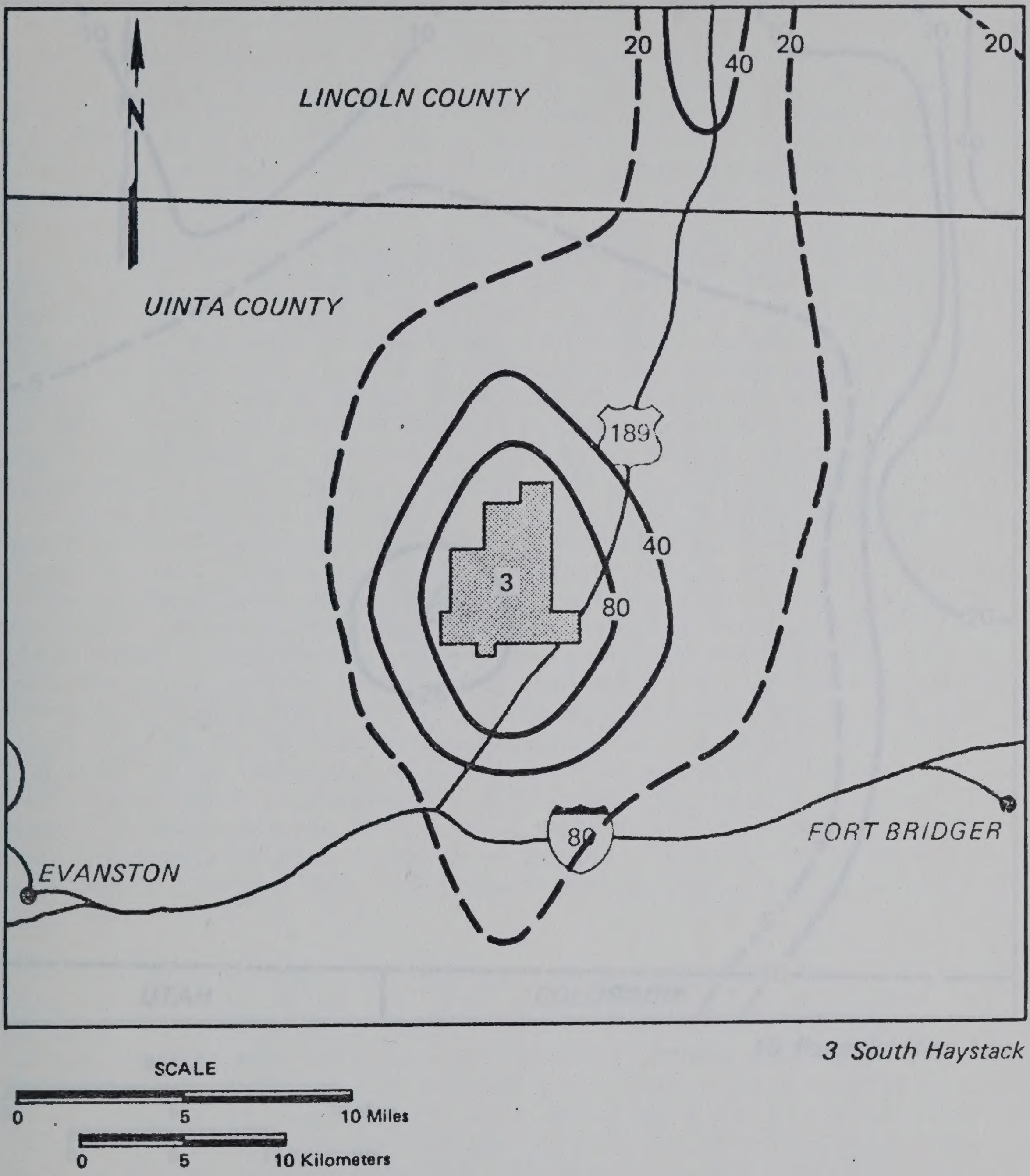

N
20
11
20
40
30N
1
2
80
KEMMERER
120
Naughton Power Plant
12
LINCOLN COUNTY
20
20
SCALE
0
5
10 Miles
0
5
10 Kilometers
1 North Block
2 Twin Creek
11,12 Existing Leases Without Mine Proposals

⊠ = Maximum Predicted Concentration = 264 μg/m^3

Map R8-28

High-Level Scenario: 1990 North Block-Twin Creek Subregional Predicted 24-Hour Average SP Concentrations (μg/m^3) Attributable to the Mines Alone

804093

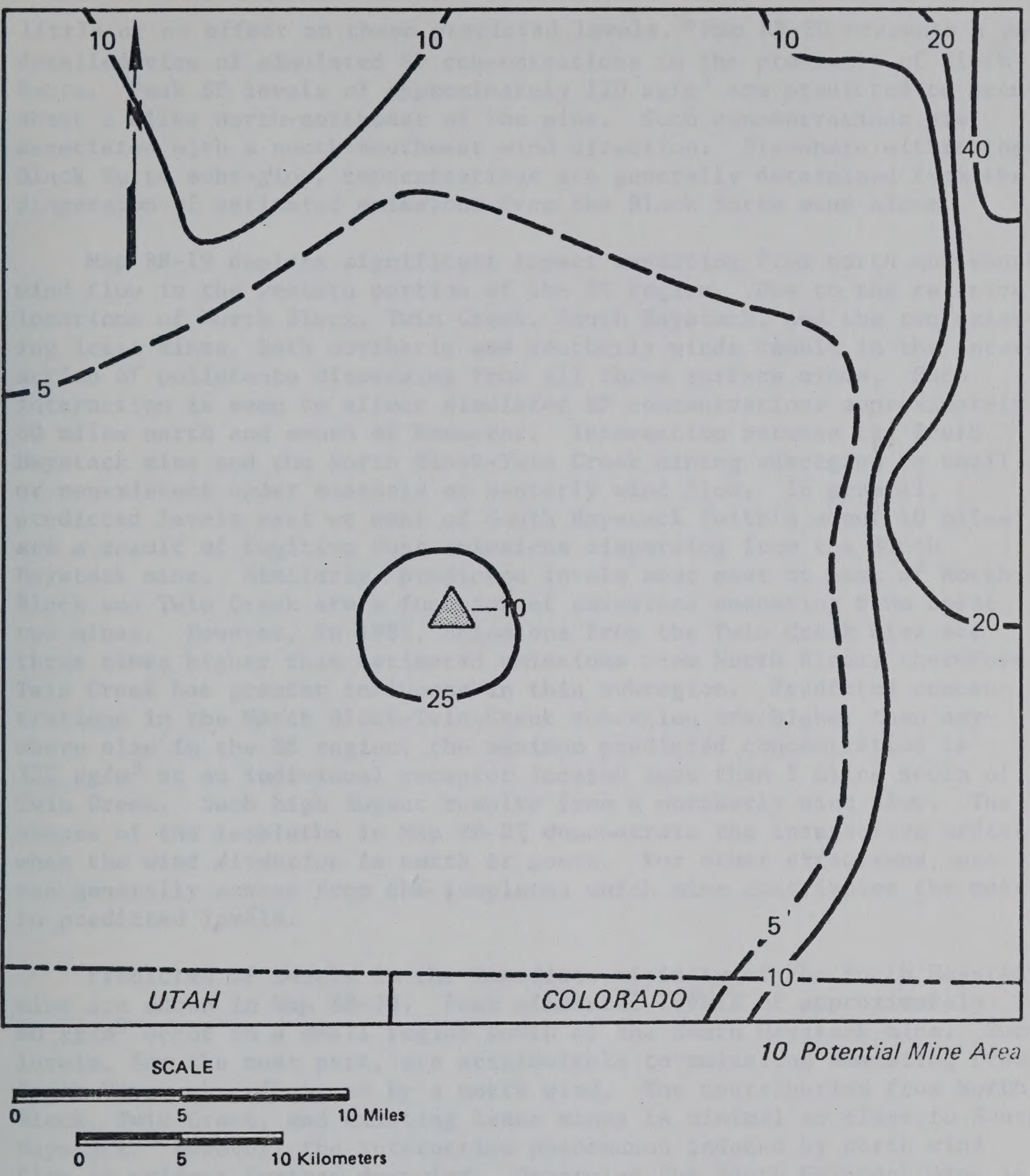

N
LINCOLN COUNTY
UINTA COUNTY
20
40
20
20
189
40
3
80
80
EVANSTON
FORT BRIDGER
3 South Haystack
SCALE
0
5
10 Miles
0
5
10 Kilometers

Map R8-29

High-Level Scenario: 1990 South Haystack Subregional

24-Hour Average SP Concentrations Attributable to the Mines Alone

801145
803347


10
10
10
20
40
5
10
25
20
5
10
UTAH
COLORADO
10 Potential Mine Area
SCALE
0
5
10 Miles
0
5
10 Kilometers

Map R8-30

High-Level Scenario: 1990 Subregional Predicted 24-Hour Average SP Concentrations About a Potential Mine Area Attributable to the Mines Alone

801146
804059

little or no effect on these predicted levels. Map R8-20 presents a more detailed view of simulated SP concentrations in the proximity of Black Butte. Peak SP levels of approximately 120 μg/m^3 are predicted to occur about 2 miles north-northeast of the mine. Such concentrations are associated with a south-southwest wind direction. Elsewhere within the Black Butte subregion, concentrations are generally determined from the dispersion of estimated emissions from the Black Butte mine alone.

Map R8-19 depicts significant impact resulting from north and south wind flow in the western portion of the ES region. Due to the relative locations of North Block, Twin Creek, South Haystack, and the two existing lease mines, both northerly and southerly winds result in the interaction of pollutants dispersing from all three surface mines. Such interaction is seen to affect simulated SP concentrations approximately 60 miles north and south of Kemmerer. Interaction between the South Haystack mine and the North Block-Twin Creek mining subregion is small or nonexistent under easterly or westerly wind flow. In general, predicted levels east or west of South Haystack (within about 40 miles) are a result of fugitive dust emissions dispersing from the South Haystack mine. Similarly, predicted levels near east or west of North Block and Twin Creek are a function of emissions emanating from these two mines. However, in 1985, emissions from the Twin Creek mine are three times higher than estimated emissions from North Block; therefore, Twin Creek has greater influence in this subregion. Predicted concentrations in the North Block-Twin Creek subregion are higher than anywhere else in the ES region; the maximum predicted concentration is 322 μg/m^3 at an individual receptor located less than 2 miles south of Twin Creek. Such high impact results from a northerly wind flow. The shapes of the isopleths in Map R8-22 demonstrate the interactive effect when the wind direction is north or south. For other directions, one can generally assess from the isopleths which mine contributes the most to predicted levels.

Predicted SP levels in the immediate vicinity of the South Haystack mine are shown in Map R8-23. Peak simulated levels of approximately 80 μg/m^3 occur in a small region south of the South Haystack mine. Such levels, for the most part, are attributable to emissions emanating from South Haystack influenced by a north wind. The contribution from North Block, Twin Creek, and existing lease mines is minimal so close to South Haystack. However, the interaction phenomenon induced by north wind flow is evident further downwind. Otherwise the South Haystack mine is the sole source of predicted levels within about 40 miles east or west of the mine site. Map R8-24 depicts simulated SP concentrations for the mine area of interest denoted MRN-10; these levels are generally attributable to emissions emanating from the MRN-10 mine.

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CH. 12-3-78 Ex. II

little or no effect on these predicted levels. Map 8B-20 presents a more detailed view of simulated SP concentrations in the proximity of Black Butte. Peak SP levels of approximately 120 µg/m³ are predicted to occur about 2 miles north-northeast of the mine. Such concentrations are associated with a south-southwest wind direction. Elsewhere within the Black Butte subregion, concentrations are generally determined from the dispersion of estimated emissions from the Black Butte mine alone.

Map 8B-19 depicts significant impact resulting from north and south wind flow in the western portion of the SB region. Due to the relative locations of North Block, Twin Creek, South Haystack, and the two existing lease mines, both northerly and southerly winds result in the interaction of pollutants dispersing from all three surface mines. Such interaction is seen to affect simulated SP concentrations approximately 60 miles north and south of Kemmerer. Interaction between the South Haystack mine and the North Block-Twin Creek mining subregion is small or nonexistent under easterly or westerly wind flow. In general, predicted levels east or west of South Haystack (within about 40 miles) are a result of fugitive dust emissions dispersing from the South Haystack mine. Similarly, predicted levels near east or west of North Block and Twin Creek are a function of emissions emanating from these two mines. However, in 1985, emissions from the Twin Creek mine are three times higher than estimated emissions from North Block; therefore, Twin Creek has greater influence in this subregion. Predicted concentrations in the North Block-Twin Creek subregion are higher than anywhere else in the SB region; the maximum predicted concentration is 322 µg/m³ at an individual receptor located less than 2 miles south of Twin Creek. Such high impact results from a northerly wind flow. The shapes of the isopleths in Map 8B-22 demonstrate the interactive effect when the wind direction is north or south. For other directions, one can generally assess from the isopleths which mine contributes the most to predicted levels.

Predicted SP levels in the immediate vicinity of the South Haystack mine are shown in Map 8B-23. Peak simulated levels of approximately 80 µg/m³ occur in a small region south of the South Haystack mine. Such levels, for the most part, are attributable to emissions emanating from South Haystack influenced by a north wind. The contribution from North Block, Twin Creek, and existing lease mines is minimal so close to South Haystack. However, the interaction phenomenon induced by north wind flow is evident further downwind. Otherwise the South Haystack mine is the sole source of predicted levels within about 40 miles east or west of the mine site. Map 8B-25 depicts simulated SP concentrations for the mine area of interest denoted NSM-10; these levels are generally attributable to emissions emanating from the NSM-10 mine.

Mining areas of interest and existing lease mines corresponding to MRN-8 through MRN-13 on Map R8-19 have an insignificant contribution to 24-hour average concentrations on a regional scale due to their low emission rates as depicted in Table R8-1. Therefore, regionally predicted SP concentrations for the high-level scenario hardly differ from the levels simulated for the most probable level of coal development discussed in Chapter 4.

For PSD increments, simulated concentrations in the Bridger Wilderness Area are less than 2 μg/m^3, which does not interfere with the 10 μg/m^3 Class I increment. The remaining portion of southwest Wyoming is designated Class II. The 37 μg/m^3 allowable PSD increment is exceeded in the vicinity of all the mine sites except that of Long Canyon, which is an underground mine.

At the present time, both the Flaming Gorge National Recreation Area and Fossil Butte National Monument are Class II regions, but have but have the potential to be redesignated to Class I. Predicted worst-case 24-hour average concentrations at Flaming Gorge are approximately 5 μg/m^3 or less than the 10 μg/m^3 Class I increment. However, at the Fossil Butte National Monument, simulated SP levels are about 20 μg/m^3, which exceeds the Class I increment, but does not exceed the allowable Class II increment of 37 μg/m^3.

The trona patch, 6 miles north of Green River, is designated an NA area. Simulated SP impact for this region is approximately 7 μg/m^3, less than 3% of the 260 μg/m^3 federal standard.

Model Predictions of 24-Hour Average Impact on SP Concentrations for 1990

The predicted impacts from the high-level scenario in 1990 are presented in Maps R8-25 through R8-30. Regionally, simulated SP concentrations range from 5 to approximately 120 μg/m^3; the highest impacts are predicted to occur in the vicinity of the mine sites. In the Rock Springs area, worst-case predicted SP levels are generally determined from fugitive dust emissions at Black Butte. Similar to 1985, emissions from Black Butte are more than three times higher than the sum of emissions from the several underground mines in the vicinity of Rock Springs. Consequently, dispersion of emissions from the Black Butte mine determine the elongated portions of the isopleths presented in Map R8-25. That is, the skewing effect is a result of the wind direction lining up the Black Butte mine with such receptors. The only significant influence resulting from Long Canyon emissions is to receptors located very close (within 3 to 5 miles) to the Long Canyon mine. Mines MRN-8 through MRN-10 and MRN-13 with such low fugitive dust

emission rates have an insignificant contribution to simulated concentrations in the eastern portion of the ES region. Predicted SP levels close to the Black Butte, Long Canyon, Winton, and Reliance mines are depicted in Maps R8-26 and R8-27. Peak concentrations of approximately 20 $\mu g/m^3$ are predicted to occur about the Long Canyon mine. These concentrations result from a northerly wind flow dispersing emissions from Long Canyon. SP concentrations of 20 $\mu g/m^3$ are also predicted to occur 12 miles southeast of Long Canyon. These predicted levels are attributable to the Black Butte mine influenced by an east-southeast wind direction. Maximum SP levels of 120 $\mu g/m^3$ are predicted to occur within 2 miles northeast of the Black Butte mine; these levels are associated with winds from the west-southwest. Elsewhere within the Black Butte subregion, predicted concentrations are generally dominated by dispersion of Black Butte's fugitive dust emissions.

In the western half of the ES region, Map R8-25 indicates significant impact resulting from north and south wind flow. Because of the relative locations of North Block, Twin Creek, South Haystack, and existing lease mines, both northerly and southerly winds result in the interaction of pollutants dispersing from all three surface mines. Such interaction is seen to affect simulated SP concentrations approximately 60 miles north and south of Kemmerer. Interaction between the South Haystack mine and the North Block-Twin Creek mining subregion is small or nonexistent under easterly or westerly wind flow. In general, predicted levels east or west of South Haystack (within about 40 miles) are dominated by fugitive dust emissions dispersing from the South Haystack mine. Similarly, predicted levels near east or west of North Block and Twin Creek are a function of emissions emanating from these two mines. However, in 1990, emissions from the Twin Creek mine are almost three times higher than estimated emissions from North Block; therefore, Twin Creek has greater influence in this subregion. Maximum predicted SP concentrations in the North Block-Twin Creek subregion are greater than 120 $\mu g/m^3$, as depicted in Map R8-28. The peak predicted concentration located approximately 2 miles south of Twin Creek is 264 $\mu g/m^3$. Note that emissions from both the Twin Creek and North Block mines decrease from 1985 to 1990 by approximately 17%. The shapes of the isopleths portray the interactive effect between the mines during northerly and southerly wind flow. Because of its high emission rate, the Twin Creek mine dominates predicted concentrations in this subregion.

Predicted SP levels about the South Haystack mine range from 20 to 80 $\mu g/m^3$ as shown in Map R8-29. Again, interaction between mines is apparent with north and south wind directions. However, within approximately 3 miles of the mine, the major portion of simulated concentrations are attributable to South Haystack. This is the case in all subregions; the interactive effect between mines is not significant at receptors located close to the mine site. Peak SP concentrations of approximately 25 $\mu g/m^3$ are predicted to occur about mine MRN-10 as shown in Map R8-30.

These simulated levels are attributable primarily to MRN-10 alone. Note that predicted concentrations northeast of the mine are slightly lower than the 1985 simulations; this is due to a decrease in emissions from the Black Butte mine from 1985 to 1990 (see Tables R4-19 and R4-20).

Mining areas of interest and existing lease mines corresponding to MRN-8 through MRN-13 on Map R8-25 have an insignificant contribution to 24-hour average concentrations on a regional scale due to their low emission rates as depicted in Table R8-1. Therefore, regionally predicted SP concentrations for the high-level scenario hardly differ from the levels simulated for the most probable level of coal development discussed in Chapter 4.

Concentrations of SP predicted to occur throughout the Class I Bridger Wilderness Area are about 1 μg/m^3, well below the 10 μg/m^3 allowable PSD increment. The allowable PSD increment for the rest of southwest Wyoming (designated Class II) is maintained regionally except in the vicinity of some of the surface mines as depicted in Maps R8-26, R8-28, and R8-29.

The Flaming Gorge Recreational Area shown on Map R8-25 and the Fossil Butte National Monument (located approximately 10 miles northwest of Kemmerer) are currently Class II regions, but may be redesignated to Class I. Concentrations of SP less than 5 μg/m^3 are predicted to occur throughout the Flaming Gorge Area, which complies with the Class I 10 μg/m^3 increment. Predicted levels at Fossil Butte are approximately 20 μg/m^3 which complies with the Class II increment, but exceeds the allowable Class I increment.

Impact from the high-level of coal development in 1990 is indicated for the NA trona patch, 6 miles north of Green River. As indicated in Map R8-25, predicted concentrations in this area are about 5 μg/m^3, less than 2% of the federal 260 μg/m^3 standard.

Gaseous Pollutants

Vehicle emissions would be the only source of gaseous air pollutants attributable to the proposed action mines. Federal and state regulations include limitations on ambient air concentrations of the vehicle-related pollutants: CO, HC, NO_2, and SO_2.

Ambient concentrations were not modeled because of the lack of detailed data on vehicle use and of applicable background data for these pollutants. However, recent studies (U.S. Department of the Interior 1976) of the impact of vehicle emissions associated with western coal mines were reviewed to estimate the probable range of impact. In these studies, concentrations of the above pollutants for similar mining

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CO.

These simulated levels are attributable primarily to NSO-10 alone. Note that predicted concentrations northeast of the mine are slightly lower than the 1985 simulations; this is due to a decrease in emissions from the Black Butte mine from 1985 to 1990 (see Tables 8A-19 and 8A-20).

Mining areas of Jacobs and existing lease mines corresponding to NSM-8 through NSM-13 on Map 8B-23 have an insignificant contribution to 24-hour average concentrations on a regional scale due to their low emission rates as depicted in Table 8B-1. Therefore, regionally predicted TP concentrations for the high-level scenario hardly differ from the levels simulated for the most probable level of coal development discussed in Chapter 4.

Concentrations of TP predicted to occur throughout the Class I Bridger Wilderness Area are about 1 ug/m^3, well below the 10 ug/m^3 allowable PSD increment. The allowable PSD increment for the rest of southwest Wyoming (designated Class II) is maintained regionally except in the vicinity of some of the surface mines as depicted in Maps 8B-24, 8B-28, and 8B-25.

The Fleming Range Traditional Area shown on Map 8B-23 and the Fossil Butte National Monument (located approximately 10 miles northwest of Kemmerer) are currently Class II regions, but may be redesignated to Class I. Concentrations of TP less than 2 ug/m^3 are predicted to occur throughout the Fleming Range area, which complies with the Class I 10 ug/m^3 increment. Predicted levels at Fossil Butte are approximately 20 ug/m^3 which complies with the Class II increment, but exceeds the allowable Class I increment.

Impact from the high-level of coal development in 1990 is indicated for the Ma Green patent, 8 miles north of Green River. As indicated in Map 8B-25, predicted concentrations in this area are about 1 ug/m^3, less than 2% of the federal 260 ug/m^3 standard.

Gaseous Pollutants

Vehicle emissions would be the only source of gaseous air pollutants attributable to the proposed action mines. Federal and state regulations include limitations on ambient air concentrations of the vehicle-related pollutants: CO, HC, NO$_2$, and SO$_2$.

Ambient concentrations were not modeled because of the lack of detailed data on vehicle use and of applicable background data for these pollutants. However, recent studies (U.S. Department of the Interior 1976) of the impact of vehicle emissions associated with western coal mines were analyzed to estimate the probable range of impact. In these studies, concentrations of the above pollutants for similar mining operations had either been modeled or estimated from standard approximation techniques. In all cases, the levels of maximum pollutant concentrations from vehicle emissions were insignificant when compared to standards.

Maximum predicted concentrations of CO ranged between 0.02 and 0.44% of the 1-hour 40,000 $\mu g/m^3$ standard. Maximum predicted HC concentrations ranged between 0.88 and 3.44% of the 3-hour 160 $\mu g/m^3$ standard. Maximum predicted NO_2 concentrations ranged between 0.60 and 3.0% of the standards, while maximum predicted concentrations of SO_2 ranged between 0.02 and 0.33% of the standards. Air quality standards for SO_2 and NO_x are shown in Table R4-64. The values represent predictions at less than one-half mile from the mines. Predictions were significantly less at distances further from the mines. Assuming similar vehicle activity for all western coal mines, the regional cumulative impact of vehicle emissions on ambient concentrations of gaseous pollutants would be minimal and insignificant compared to their respective standards.

Cumulative Impacts on Air Quality

This section presents a discussion of cumulative impacts on TSP levels in the ES region, i.e., the summation of predicted SP concentrations attributable to the mines discussed in the previous sections in combination with Winton and Reliance and projected background concentrations. Winton and Reliance were modeled as in the low-level scenario and simulated impacts were determined. A more comprehensive discussion of the background as well as a quantitative range of background levels throughout the ES region is presented in Chapter 4. Similar to the low-level scenario, the mid-points of the background ranges were graphically combined with mine impact simulations for a pictorial representation of cumulative impacts. Use of these background range mid-points is arbitrary and applied for illustrative purposes only; the reader can just as easily choose any point within the projected ranges to determine cumulative impacts. These simulated 1985 and 1990 annual and 24-hour average cumulative TSP impacts are presented in Maps R8-31 through R8-34, respectively. Each of the cumulative impact maps depicts isolated points of maximum impact. These "hot spots" are denoted by letters A through H.

Model Predictions of Annual Average Cumulative Impacts on TSP Concentrations. The highest background levels are projected to occur within the industrial and urban areas of Sweetwater County. When combined with simulated mine concentrations, cumulative levels for 1985 and 1990 are predicted to range from 24 to 46 $\mu g/m^3$ in the vicinity of the Jim Bridger Power Plant and the trona patch; predicted mine contributions

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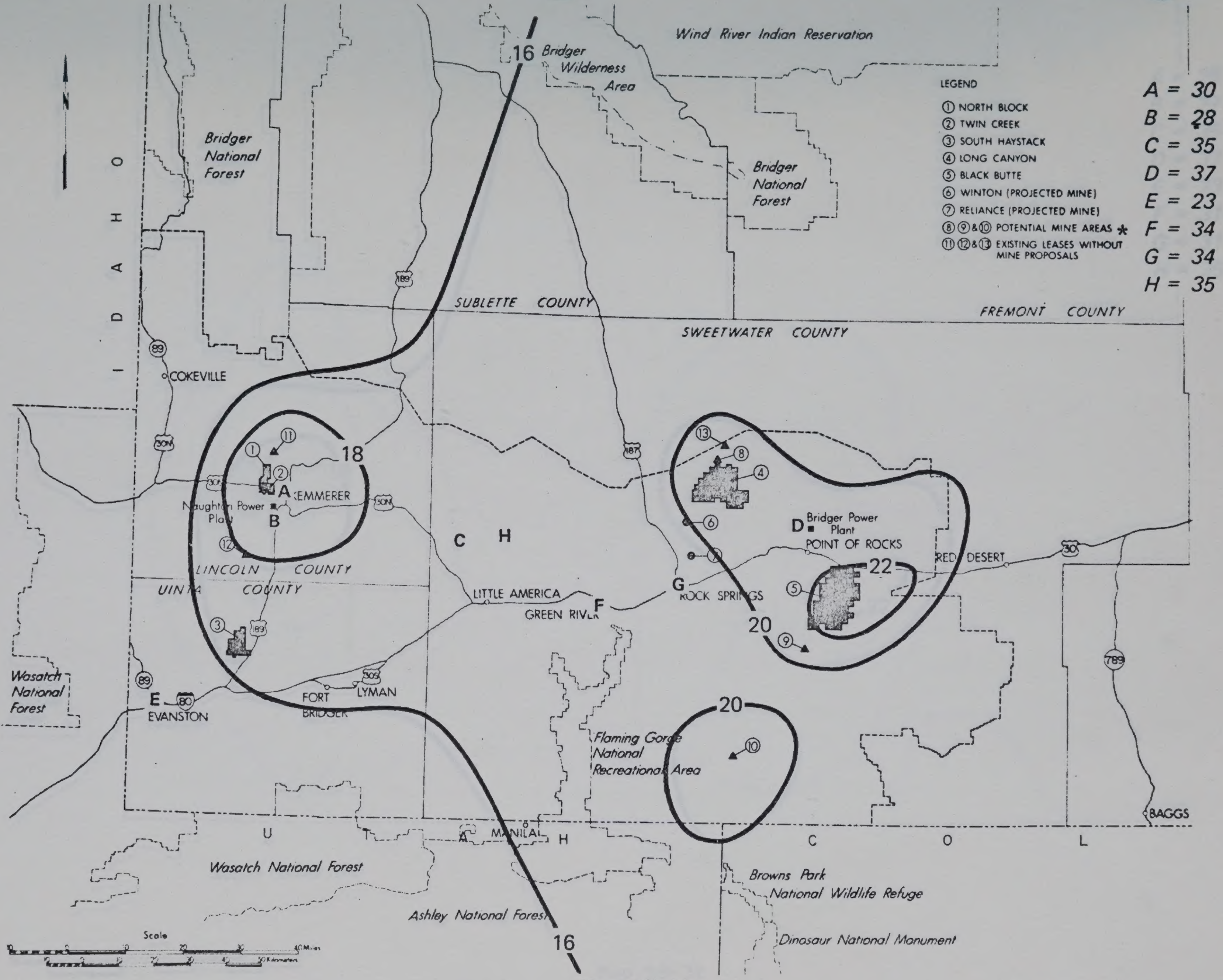
16
Bridger Wilderness Area
Wind River Indian Reservation
LEGEND
① NORTH BLOCK
② TWIN CREEK
③ SOUTH HAYSTACK
④ LONG CANYON
⑤ BLACK BUTTE
⑥ WINTON (PROJECTED MINE)
⑦ RELIANCE (PROJECTED MINE)
⑧ ⑨ & ⑩ POTENTIAL MINE AREAS *
⑪ ⑫ & ⑬ EXISTING LEASES WITHOUT MINE PROPOSALS
N
I D A H O
Bridger National Forest
Bridger National Forest
189
SUBLETTE COUNTY
FREMONT COUNTY
SWEETWATER COUNTY
89
COKEVILLE
30N
18
A
KEMMERER
Naughton Power Plant
B
C
H
187
D
Bridger Power Plant
POINT OF ROCKS
22
RED DESERT
30
LINCOLN COUNTY
UINTA COUNTY
LITTLE AMERICA
GREEN RIVER
F
G
ROCK SPRINGS
20
189
Wasatch National Forest
89
E
EVANSTON
80
FORT BRIDGER
LYMAN
789
20
Flaming Gorge National Recreational Area
BAGGS
U T A H
MANILA
C O L
Wasatch National Forest
Browns Park National Wildlife Refuge
Ashley National Forest
Dinosaur National Monument
16
Scale
Miles
Kilometers

A = 30
B = 28
C = 35
D = 37
E = 23
F = 34
G = 34
H = 35

Map R8-31

High-Level Scenario: 1985 Cumulative Predicted Annual Average TSP Concentrations ($\mu g/m^3$)

*Equivalent to "mine areas of interest."

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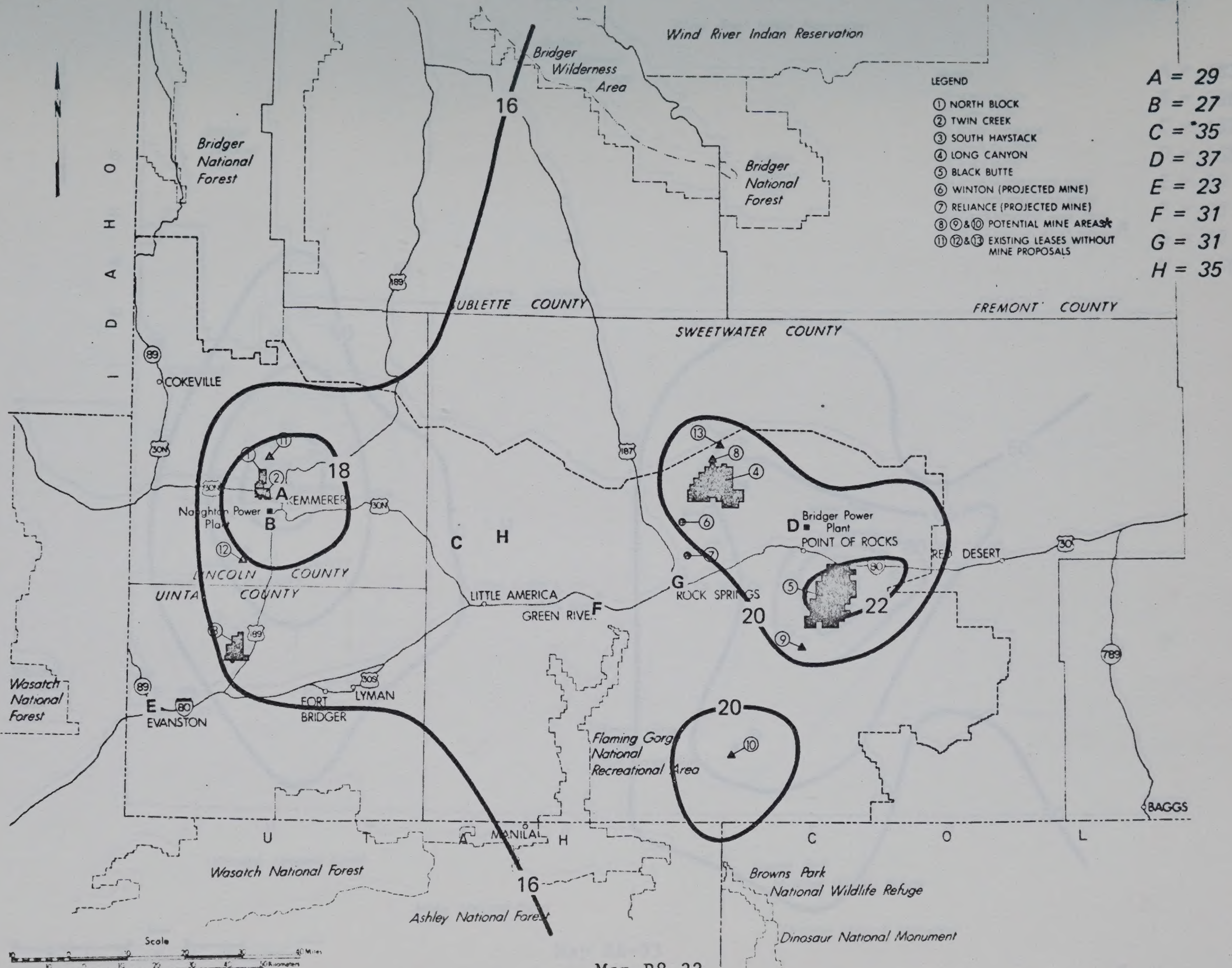

Wind River Indian Reservation
Bridger Wilderness Area
Bridger National Forest
Bridger National Forest
LEGEND
① NORTH BLOCK
② TWIN CREEK
③ SOUTH HAYSTACK
④ LONG CANYON
⑤ BLACK BUTTE
⑥ WINTON (PROJECTED MINE)
⑦ RELIANCE (PROJECTED MINE)
⑧ ⑨ & ⑩ POTENTIAL MINE AREAS*
⑪ ⑫ & ⑬ EXISTING LEASES WITHOUT MINE PROPOSALS
A = 29
B = 27
C = 35
D = 37
E = 23
F = 31
G = 31
H = 35
N
IDAHO
16
18
20
22
20
16
SUBLETTE COUNTY
FREMONT COUNTY
SWEETWATER COUNTY
COKEVILLE
KEMMERER
Naughton Power Plant
LINCOLN COUNTY
UINTA COUNTY
LITTLE AMERICA
GREEN RIVER
ROCK SPRINGS
Bridger Power Plant
POINT OF ROCKS
RED DESERT
Wasatch National Forest
EVANSTON
FORT BRIDGER
LYMAN
Flaming Gorge National Recreational Area
MANILA
UTAH
COLORADO
BAGGS
Wasatch National Forest
Ashley National Forest
Browns Park National Wildlife Refuge
Dinosaur National Monument
Scale
Miles
Kilometers

Map R8-32

High-Level Scenario: 1990 Cumulative Predicted Annual Average TSP Concentrations (μg/m^3)

*Equivalent to "mine areas of interest."

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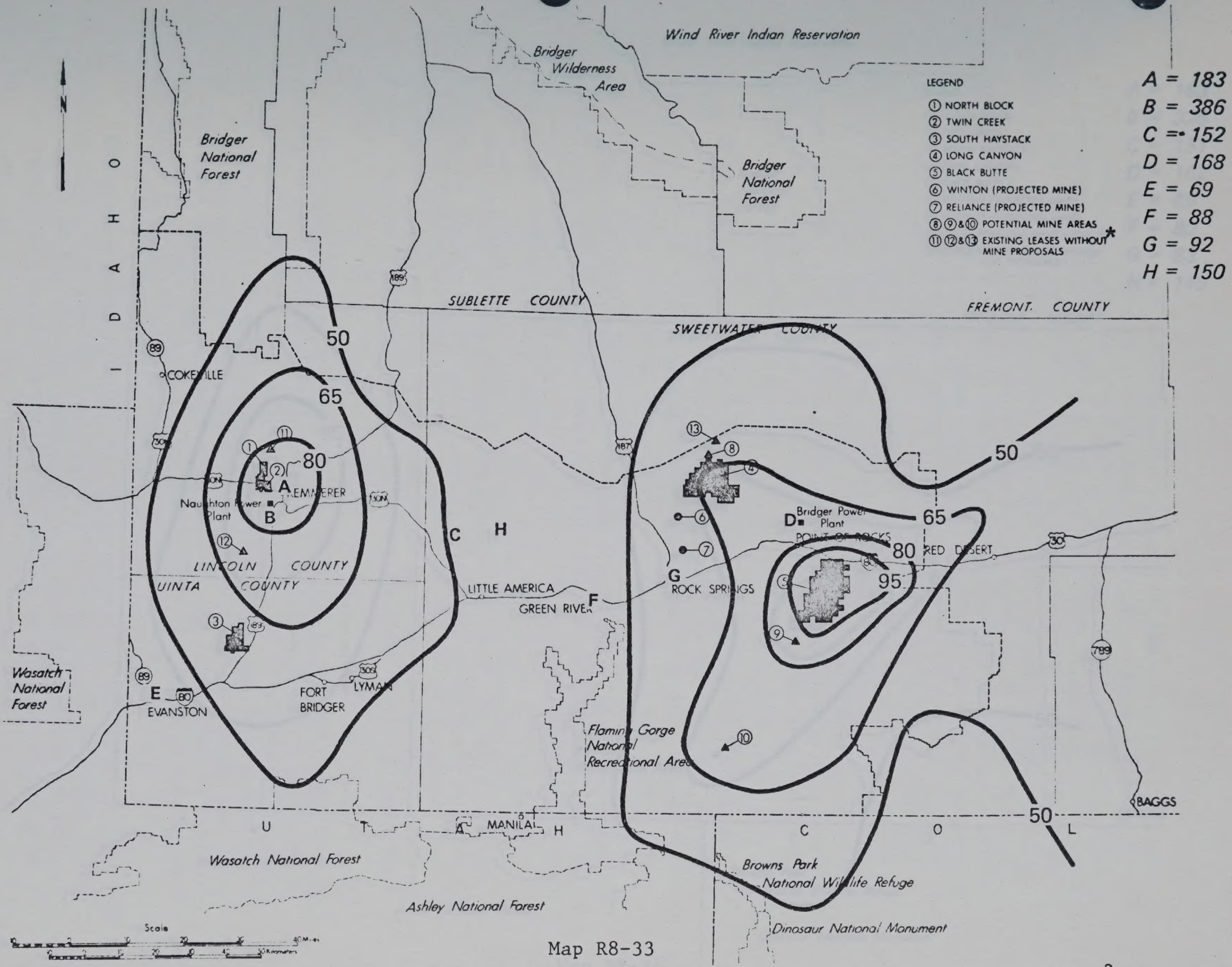
N
IDAHO
Bridger National Forest
Bridger Wilderness Area
Wind River Indian Reservation
Bridger National Forest
LEGEND
① NORTH BLOCK
② TWIN CREEK
③ SOUTH HAYSTACK
④ LONG CANYON
⑤ BLACK BUTTE
⑥ WINTON (PROJECTED MINE)
⑦ RELIANCE (PROJECTED MINE)
⑧ ⑨ & ⑩ POTENTIAL MINE AREAS
⑪ ⑫ & ⑬ EXISTING LEASES WITHOUT* MINE PROPOSALS
A = 183
B = 386
C = 152
D = 168
E = 69
F = 88
G = 92
H = 150
SUBLETTE COUNTY
FREMONT COUNTY
SWEETWATER COUNTY
COKEVILLE
50
65
80
A
KEMMERER
Naughton Power Plant
B
C
H
LINCOLN COUNTY
UINTA COUNTY
LITTLE AMERICA
GREEN RIVER
F
G
ROCK SPRINGS
D
Bridger Power Plant
POINT OF ROCKS
RED DESERT
95
E
EVANSTON
FORT BRIDGER
LYMAN
Wasatch National Forest
Flaming Gorge National Recreational Area
MANILA
BAGGS
UTAH
COLO
Wasatch National Forest
Ashley National Forest
Browns Park National Wildlife Refuge
Dinosaur National Monument
Scale
40 Miles
Kilometers

Map R8-33

High-Level Scenario: 1985 Cumulative Predicted 24-Hour Average TSP Concentrations ($\mu g/m^3$)

*Equivalent to "mine areas of interest."

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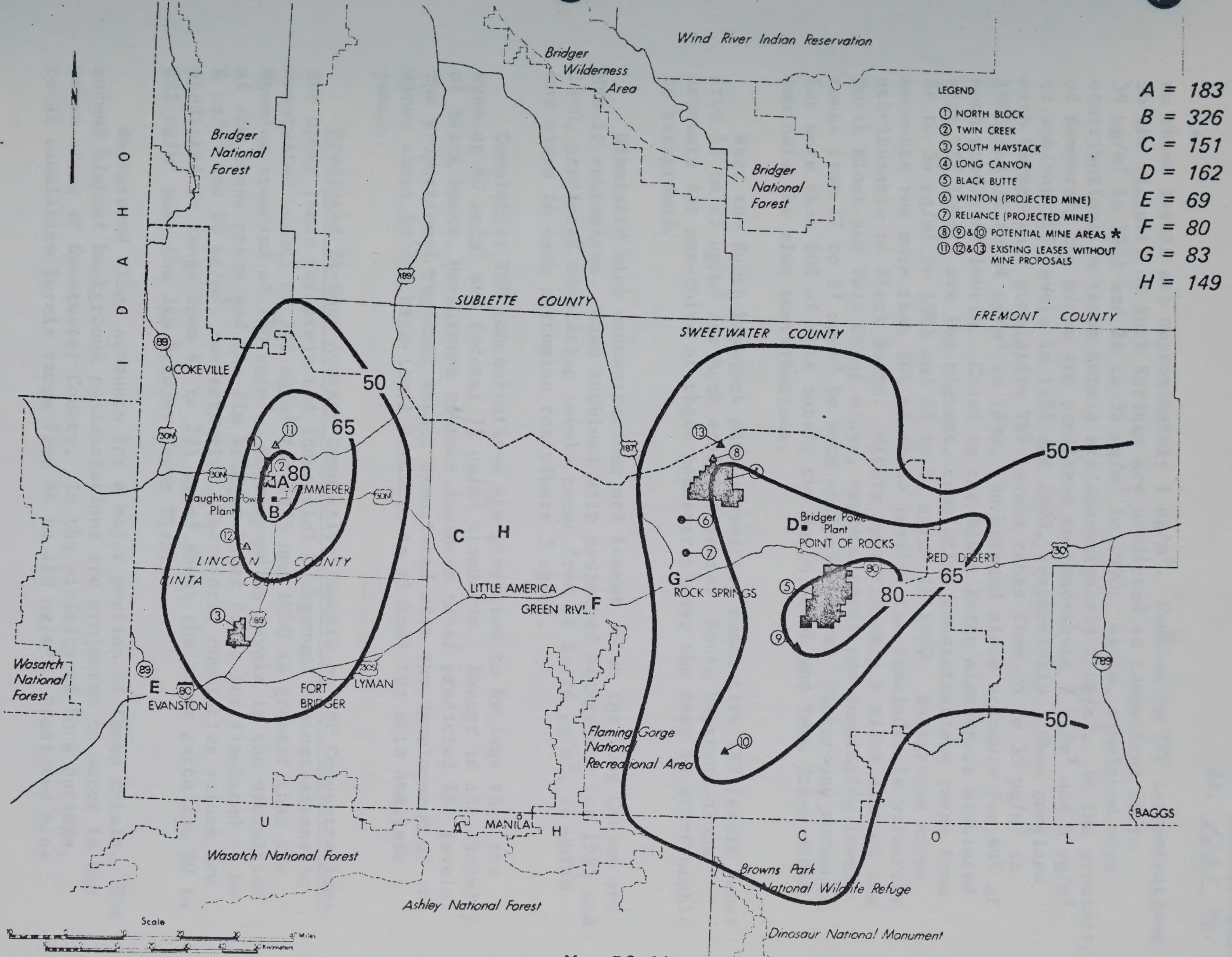
Wind River Indian Reservation
Bridger Wilderness Area
Bridger National Forest
Bridger National Forest
LEGEND
① NORTH BLOCK
② TWIN CREEK
③ SOUTH HAYSTACK
④ LONG CANYON
⑤ BLACK BUTTE
⑥ WINTON (PROJECTED MINE)
⑦ RELIANCE (PROJECTED MINE)
⑧⑨&⑩ POTENTIAL MINE AREAS *
⑪⑫&⑬ EXISTING LEASES WITHOUT MINE PROPOSALS
A = 183
B = 326
C = 151
D = 162
E = 69
F = 80
G = 83
H = 149
N
IDAHO
SUBLETTE COUNTY
FREMONT COUNTY
SWEETWATER COUNTY
LINCOLN COUNTY
UINTA COUNTY
COKEVILLE
KEMMERER
Naughton Power Plant
Bridger Power Plant
POINT OF ROCKS
RED DESERT
LITTLE AMERICA
GREEN RIVER
ROCK SPRINGS
EVANSTON
FORT BRIDGER
LYMAN
MANILA
BAGGS
Wasatch National Forest
Wasatch National Forest
Ashley National Forest
Flaming Gorge National Recreational Area
Browns Park National Wildlife Refuge
Dinosaur National Monument
UTAH
COLORADO
50
65
80
50
65
80
50
Scale
Miles
Kilometers

Map R8-34

High-Level Scenario: 1990 Cumulative Predicted 24-Hour Average TSP Concentrations (μg/m^3)

*Equivalent to "mine areas of interest."

to these levels are approximately 1 μg/m³. Cumulative TSP concentrations in the vicinity of Rock Springs are predicted to range from 29 to 39 μg/m³ in 1985 and 26 to 36 μg/m³ in 1990. Again, simulated mine contributions to these totals are approximately 1 μg/m³. In the proximity of Kemmerer, the mines are predicted to contribute 7 μg/m³ and 6 μg/m³ to ambient TSP levels in 1985 and 1990, respectively. When combined with background, cumulative TSP levels range from 25 to 35 μg/m³ in 1985 and 24 to 34 μg/m³ in 1990. Background alone accounts for 80% of such predicted levels. Close to the Black Butte mine where simulated mine TSP levels are the highest, cumulative concentrations range from 24 to 34 μg/m³ in 1985 and 22 to 32 μg/m³ in 1990. Background alone accounts for more than 50% of these levels; the remainder is primarily attributable to Black Butte. Within approximately 6 miles east of the North Block and Twin Creek mines, maximum predicted cumulative levels range from 17 to 27 μg/m³ in both analysis years. Background accounts for more than 60% of this total; the North Block and Twin Creek mines dominate the mine contributions.

Near the South Haystack mine, predicted cumulative TSP levels range from 15 to 25 μg/m³ for both analysis years. South Haystack alone accounts for one-third of these concentrations; the rest is attributable to background.

Simulated mine concentrations are lowest about the Long Canyon and MRN-10 subregions. When combined with projected background for 1985 and 1990, predicted cumulative levels range from 16 to 26 μg/m³, to which the mines in each subregion contribute 3 μg/m³.

Cumulative TSP concentrations are predicted to be less than the Wyoming 60 μg/m³ and federal 75 μg/m³ standards. Except in the vicinity of Black Butte, background sources dominate total predicted TSP levels. The proportional regional impact associated with the development of the mines alone in the high-level scenario is minimal for both analysis years.

Predicted 24-Hour Average Cumulative Impacts on TSP Concentrations. The upper limit for projected industrial background concentrations in Sweetwater County of 225 μg/m³ for 1985 and 1990 is greater than the Wyoming standard of 150 μg/m³. Corresponding levels in the vicinities of the trona patch and the Jim Bridger Power Plant are simulated to be 6 μg/m³ and 20 μg/m³, respectively. Therefore, cumulative values are predicted to range from 66 to 231 μg/m³ about the trona patch and 80 to 245 μg/m³ near the Jim Bridger Power Plant.

Background alone accounts for a major portion of these totals. The second highest background concentrations are projected to occur in the urban areas of Sweetwater County. In the vicinity of Rock Springs, total cumulative levels range from 64 to 119 μg/m³. Predicted mine

contributions to these levels are less than 14%, and they are attributable primarily to Black Butte. As indicated earlier, maximum mine simulated concentrations of 323 and 264 µg/m^3 occur approximately 2 miles south of Twin Creek in 1985 and 1990, respectively (refer to Maps R8-22 and R8-28). When combined with projected background, resultant total concentrations range from 373 to 398 µg/m^3 in 1985 and 314 to 339 µg/m^3 in 1990. The Twin Creek (predominately) and North Block mines line up under the influence of a northerly wind flow to account for greater than 80% of these total concentrations. Mine MRN-11 has little effect on these total concentrations due to its low emission rate (see Table R8-1). In Kemmerer, approximately 2 miles east of Twin Creek, predicted cumulative levels range from 170 to 195 µg/m^3 for 1985 and 1990. Background contributes less than 30% of these levels; Twin Creek (primarily) and North Block comprise most of the simulated mine impacts.

North-northeast of Black Butte, peak mine simulations are on the order of 120 µg/m^3 for 1985 and 1990. When combined with Sweetwater County rural background, total predicted ambient levels range from 150 to 175 µg/m^3, which is greater than the Wyoming standard but less than the NAAQS. The emissions emanating from Black Butte comprise a major portion of these totals. Predicted impact from the mine area of interest (MRN-9) is negligible. Second highest simulated cumulative TSP levels about Black Butte range from 110 to 135 µg/m^3, to which the Black Butte mine contributes more than 60%. Maximum mine simulations are also on the order of 80 µg/m^3 within 2 to 3 miles of the South Haystack mine for analysis years 1985 and 1990 (refer to Maps R8-23 and R8-29). When combined with Uinta County rural background, ranges of 110 to 130 µg/m^3 characterize cumulative TSP levels. The South Haystack mine alone comprises more than 60% of these total concentrations. Cumulative levels about the Long Canyon mine range from 50 to 75 µg/m^3. Long Canyon and surrounding mines contribute approximately 10 to 20 µg/m^3 to such levels, the remainder is attributable to rural background in Sweetwater County.

In the vicinity of potential mine area MRN-10, peak predicted cumulative levels about the mine range from 55 to 80 µg/m^3 in 1985 and 1990, as depicted in Maps R8-24 and R8-30. Mine MRN-10 contributes 25 µg/m^3 to these levels, the rest is attributable to background. As indicated in Table R8-1, this mine is associated with an estimated annual emission rate that is at least 50% higher than any other mine area of interest or existing lease mine. Consequently, predicted impact from this mine is greater than the additional mines comprising the high-level scenario. However, compared to the emission rates of the five proposed action mines, MRN-10 is a relatively minor source of fugitive dust. In fact, on a regional scale, predicted impacts associated with mines MRN-8 through MRN-13, which define the high-level scenario, are insignificant.

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Elsewhere in the ES region, cumulative TSP levels are predicted to be lower than the 150 $\mu g/m^3$ Wyoming standard, and they become quite low as distance from the mine sites increases. Regionally, background levels dominate predicted cumulative levels with increased distance from the mine sites.

Natural catastrophes, such as coal fires and drought, are other potential sources of particulate emissions. Associated impacts are difficult to assess quantitatively, although maximum air quality degradation would occur on a very local scale. A qualitative discussion relative to such catastrophes is presented in Chapter 4.

Cumulative impacts on gaseous pollutants (CO, HC, NO_2, and SO_2) are similar to those associated with the proposed actions and, therefore, insignificant when compared to the standards. Refer to Chapter 4 for a more detailed discussion.

Indirect Air Quality Impacts

Additional air pollutant emissions would result from indirect sources related to the high-level coal development scenario. Consequently, baseline SP concentrations are also expected to increase and have been projected to future analysis years; these projected levels are equivalent to the ranges presented in Table R8-2. The SP concentrations simulated for the high-level mines have been combined with projected baseline levels to determine the cumulative impacts discussed in the previous section.

Quantitative indirect source impacts to variations in baseline SO_2 and NO_x concentrations are unknown (see Chapter 2). However, the contributions from the mines are expected to be negligible.

Probable Cumulative Regional Impacts

A brief enumeration on the transport of aerosols and their possible effects on climate is presented in the Chapter 2. However, the available data do not provide a firm basis for conclusive statements about what role high-level coal development activities would play in altering the ES region's existing climate over the next 15 years.

Visibility

The method used to evaluate the impact of the high-level scenario on visibility is identical to the technique described in Chapter 4. Regional background visibilities are assumed to be 40 miles for each year based on current visibility observations and evaluation of projected regional background TSP values.

In 1985, for the high-level scenario considered, worst-case 24-hour SP concentrations attain values as high as 323 $\mu g/m^3$ in the vicinity of the proposed North Block and Twin Creek mines. This corresponds to a visibility of 20.1 miles, assuming a background of 40 miles. Most of the region, however, is outside the 20 $\mu g/m^3$ isopleth, which corresponds to a visibility of 37.7 miles, a reduction of 2.3 miles from the background.

Concentrations in the Bridger Wilderness Area (Class I) are between 1 and 2 $\mu g/m^3$. This level of SP yields a visibility of 39.8 miles for a reduction of less than 0.7% from the background. In the vicinity of Flaming Gorge National Recreational Area (Class II), SP values are between 6 and 7 $\mu g/m^3$, giving visibilities of 39.2 miles (visibility degradation 2.1%). At Fossil Butte, concentrations are approximately 25 $\mu g/m^3$. The computed visibility and visibility degradation are 37.2 miles and 7.1%, respectively.

For 1990, worst-case 24-hour TSP concentrations attain values as high as 264 $\mu g/m^3$ in the vicinity of the proposed North Block and Twin Creek mines. This corresponds to a visibility of 22.1 miles, assuming a background of 40 miles. Most of the region, however, is outside the 20 $\mu g/m^3$ isopleth, which corresponds to a visibility of 37.7 miles, a reduction of 2.3 miles from the background.

Concentrations in the Bridger Wilderness Area (Class I) are about 1 $\mu g/m^3$. This level of TSP yields a visibility of 39.9 miles, for a reduction of less than 0.3% from the background. In the vicinity of Flaming Gorge National Recreational Area (Class II), TSP values are between 3 and 4 $\mu g/m^3$, giving a visibility of 39.5 miles (visibility degradation 1.3%). At Fossil Butte, concentrations are approximately 22 $\mu g/m^3$. The computed visibility and visibility degradation are 37.5 miles and 6.3%, respectively.

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